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PROGRESS REPORT
No. 10

December 1, 1984 - February 28, 1985

MMS Contract 14-08-001-21169, Mod. 3
(LSU Project No. 127-45-5115)
Effective Date: August 26, 1982
Expiration Date: October 1, 1987

on

THE DEVELOPMENT OF IMPROVED BLOWOUT PREVENTION SYSTEMS FOR OFFSHORE DRILLING OPERATIONS

Submitted to
The Minerals Management Service
United States Department of the Interior
Reston, Viriginia

Adam T. Bourgoyne, Jr.

by

Petroleum Engineering Department
Louisiana State University

RESEARCH OBJECTIVES

The primary objectives of the research are:

1. The development of an improved blowout prevention system through the integration of measurements while drilling (MWD) and well control technologies.
2. The development of improved diverter systems for offshore operations.

Funding to date has included the following subtasks:

1.1.1 Determine the data requirements (parameters and speed of transmission) for automated well control system. Experimental study, (without secondary kicks) of parameters needed, time urgency, accuracy requirements, redundancy requirements, and trade offs.

1.1.2 Determination of additional data requirements for overall well control strategy including surface data.

1.2.1 Evaluate electrical telemetery technique as data rate alternative to conventional mud pulse telemetry.

1.2.2 Select best MWD approach

1.3.1 Define and develop appropriate new hardware for control of system

2.1 Review of available technology and current field practices on design and use of diverters on offshore drilling rigs.

2.2 Review failures and cause of failures that have occured in offshore diverter systems.

2.3 Use of systems analysis approach to develop computer model of reservoir/well/diverter system.

2.4 Experimental verification of computer model of diverter system.

2.6 Literature and experimental study of erosion reduction techniques in diverter system (including bends).

2.7 Experimental and computer study of diverter plugging by produced solids.

3.1 Improved surface and near surface kick detection for floating drilling operations.

PROGRESS

Work on the various phases of the project has continued without major problems. Two budget planning updates were prepared during this period which addresses the progress made to date and proposes what is needed for next years funding. Copies of these proposals are attached in Appendix A.

The 10,000 ft. buried flow loop has been completed. The vertical storage cylinders for gas compression and for the model diverter system have been successfully drilled and cased. The acquisition of surface well head equipment needed for these cased boreholes are still in progress.

The cost of preparing the experimental flow loop and vertical boreholes is running about 30% higher than anticipated. However, some additional funding in the form of unrestricted grants and equipment donations have been obtained, and it is still anticipated that the projects can be completed within the contract costs.

SIGNIFICANT CHANGES

No significant changes have been required during the reporting period.

BUDGET PLANNING UPDATE

for

MMS Contract 14-08-001-21169, Mod. 3
(LSU Project No. 127-45-5115)

on

THE DEVELOPMENT OF IMPROVED BLOWOUT PREVENTION SYSTEMS FOR OFFSHORE DRILLING OPERATIONS

Submitted to
The Minerals Management Service
United States Department of the Interior
Reston, Virginia

by
Petroleum Engineering Department
Louisiana State University

January, 1985

BUDGET PLANNING UPDATE

for

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on

THE DEVELOPMENT OF IMPROVED BLOWOUT PREVENTION SYSTEMS FOR OFFSHORE DRILLING OPERATIONS

Submitted to
The Minerals Management Service
United States Department of the Interior
Reston, Virginia

by

Adam T Bourgoyne Jr

Adam T. Bourgoyne, Jr.
Principal Investigator

Julius P. Langlinais

Julius P. Langlinais
Co-Principal Investigator

Board of Supervisors
of
LOUISIANA STATE UNIVERSITY

CONTENTS

I. INTRODUCTION

The Petroleum Engineering department at LSU has played an active role over the past decade in well control research and in training of industry personnel in present-day methods of well control. With the help of both industry and government modern training and research facilities centered around two 6000 ft wells were equipped to model well control operations conducted both in the shallow water marine environment of the continental slope and in deepwater offshore operations. A three million dollar expansion of this facility was recently achieved through the combined support of a consortium of 60 companies in the petroleum industry and through a research grant funded by the U. S. Minerals Management Service (MMS).

On March 24, 1982, a workshop was conducted at LSU to assist in the formulation of a long range plan for future well control research. The participants included (1) members of the industry advisory panel to the LSU Blowout Prevention Research Center (2) researchers currently being supported by MMS, and (3) representatives of various MMS districts. Twenty-one desirable projects were identified by this group. The top ten projects are listed in Table 1 along with a composite priority level assigned by the workshop panel.

A five year research plan was made in a proposal to MMS for developing improved well control systems for deep water offshore drilling operations. The proposed five year plan incorporates many of the high priority items identified at the LSU Well Control Workshop. In October, 1983, MMS Contract No. 14-12-001-21169, Mod. 2 was issued for LSU to

Table 1 - Recommendations made at March 24, 1982 LSU Well Control Workshop

Priority Level	Research Area	Votes Received Assuming Funding For following number of projects: One,	Two,	Three,	Four,	or Five
1	Feasibility Study on Use of MWD Technology in Well Control Operations on Floating Vessels	6	9	9	10	11
2	Study of Well Control Operations with Simultaneous Formation Fracture	3	10	12	16	17
3	Well Control Operations for Short Casing Strings (Diverter Systems)	3	5	8	12	14
4	Improved Procedures for Handling Upward Gas Migration during stripping or Snubbing Operations	1	3	5	5	8
5	Improved System for Detecting Gas in Mud at Depth (as opposed to present surface detectors)	2	3	5	5	7
6	Study of Upward Gas Migration in Slant (Directional) Boreholes	1	2	3	5	7
7	Scale-up of Fluidic Pulse Telemetry System to longer systems with varying mud properties	0	1	3	4	5
8	Determination of Minimum Number of Requisite Parameters via MWD for safe drilling operations	1	1	1	3	5
9	Scale-up of Ongoing Fire Suppression System Development for Offshore Drilling	2	3	3	4	4
10	Study of Potential Problems due to Gas Hydrate Formation in Subsea Well Control Equipment in Deep Water	0	3	4	4	4

begin work on the first year of the five year plan. In October, 1984, the second year of the proposed plan was funded. In this document, the progress which has been made is summarized, and a budget update is provided for maintaining the project through the third year.

II. GENERAL RESEARCH PROGRAM OBJECTIVES AND TIMETABLE

The primary objective of the research project is to increase the efficiency and safety of offshore drilling operations. This would be accomplished through the development of improved blowout prevention systems. The two main systems included in the study are (1) the high pressure emergency circulating system and choke used to circulate formation fluids from a well under pressure, and (2) the diverter system which must be employed prior to setting sufficient casing to allow use of the high pressure system. Additional objectives deal with improved kick detection systems and complications that can develop as a result of formation fracture, directional drilling operations, or off-bottom kicks.

The overall research plan can be divided into six overall tasks. Several of these tasks can be subdivided into a number of subtasks. These tasks and subtasks are:

Task	Subtask	Description
1		Development of an improved blowout prevention system through the integration of measurements while drilling (MWD) and well control technologies.
	1.1	Determine the data requirements (parameters and speed of transmission) for automated well control system.
	1.1.1	Experimental study, (without secondary kicks) of parameters needed, time urgency, accuracy requirements, redundancy requirements, and trade offs.
	1.1.2	Determination of additional data requirements for overall well control strategy including surface data.

Task	Subtask	Description
	1.2	Selection of MWD System compatible with well control application.
	1.2.1	Evaluate electrical telemetry technique as high data rate alternative to conventional mud pulse telemetry.
	1.2.2	Select best available MWD approach.
	1.3	Engineering development of improved Blow-out Prevention System.
	1.3.1	Define and develop appropriate new hard-ware for control of system.
	1.3.2	Develop Process Control Computer and com-puter logic.
	1.3.3	Integrate Process Control Computer into Well Control System.
	1.3.4	Experimental verification of Process Con-trol Computer logic with risk of secondary kicks included in experimental programs.
2		Development of improved Diverter System for offshore operations.
	2.1	Review of available technology and current field practices on design and use of diverters on offshore drilling rigs.
	2.2	Review failures and cause of failures that have occurred in offshore diverter sys-tems.
	2.3	Use of systems analysis approach to de-velop computer model of reservoir/well/ diverter system.
	2.4	Experimental verification of computer model with scaled model of diverter sys-tem.
	2.5	Computer study of feasibility of maintain-ing an optimal backpressure during opera-tion of diverter system.
	2.6	Literature and experimental study of erosion reduction techniques in diverter system (including bends).

Task	Subtask	Description
	2.7	Experimental and computer study of diverter plugging by produced solids.
	2.8	Experimental evaluation of alternative diverter designs.
	2.9	Study of marine riser as part of diverter system.
	2.10	Design of improved diverter systems for bottom supported rigs and floating drilling vessels.
3		Development of improved system for kick detection for floating drilling vessels.
	3.1	Improved surface and near surface kick detection system for floating drilling operation.
	3.2	Pore pressure determination and kick detection assisted by MWD technology.
4		Study of well control with simultaneous formation fracture.
	4.1	Development of computer model.
	4.2	Experimental verification of computer model.
	4.3	Computer study to identify cases where well control with simultaneous formation fracture are feasible or even beneficial.
5		Study of upward gas migration in slant (directional) boreholes.
	5.1	Experimental study.
	5.2	Development of computer model.
6		Development of improved blowout prevention system for off-bottom kicks.
	6.1	Development of computer model.
	6.2	Use of computer model to develop improved technique for handling upward gas migration during stripping operations.
	6.3	Use of computer model to evaluate multistage off-bottom kill procedure.

An updated timetable for accomplishing the general research program is shown in Figure 1. The current year funding (1984-85), for subtasks 1.2.2, 1.3.1, and 2.4, 2.7 and 3.1, was approved and is effective through September 30, 1985.

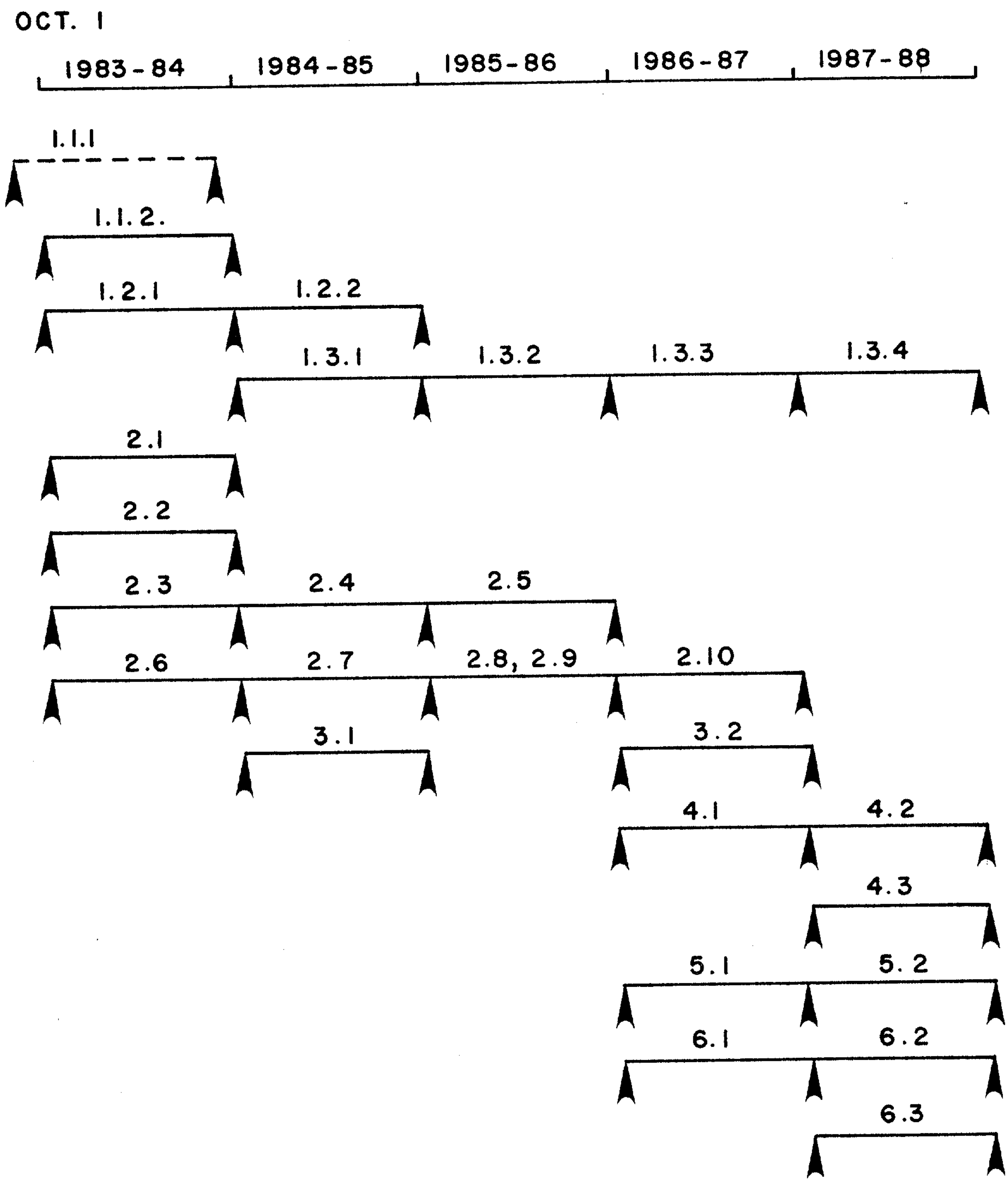

FIGURE 1. RESEARCH TIMETABLE

III. RESEARCH PROGRAM PROGRESS AND DIRECTION

The research effort to date has been directed into two major blowout prevention areas. The first area (Task 1) includes improved well control systems used for circulating out a kick under pressure. The second area (Task 2) includes improved diverter systems, which must be employed prior to setting sufficient casing to allow use of the high pressure well control system. A third area, dealing with improved kick detection systems, has also been initiated.

Organization of Research Effort

The research program has been organized under the direction of Dr. A. T. Bourgoyne, Jr., who has overall supervisory responsibility for both phases of the project. Other co-principal investigators involved in the project include Dr. W. R. Holden, Dr. J. P. Langlinais, and Dr. W. R. Whitehead. In addition, Dr. R. S. Desbrandes, another senior faculty member with considerable expertise in the well control area, has become available for work on the project. Dr. Desbrandes is currently scheduled to do a portion of the work originally scheduled for Dr. A. T. Bourgoyne, Jr.

The current organizational structure of the research project is shown in Figure 2. Engineering support is provided by James H. Sykora for assistance in designing, constructing, and carrying out all of the experimental research conducted at the research well facility. Dr. W. R. Holden has been supervising the experimental work aimed at the development of an improved well control system. Assisting him with this work is Don Remson, an M.S. student. All of the currently available automatic choke systems have been installed at the LSU research well

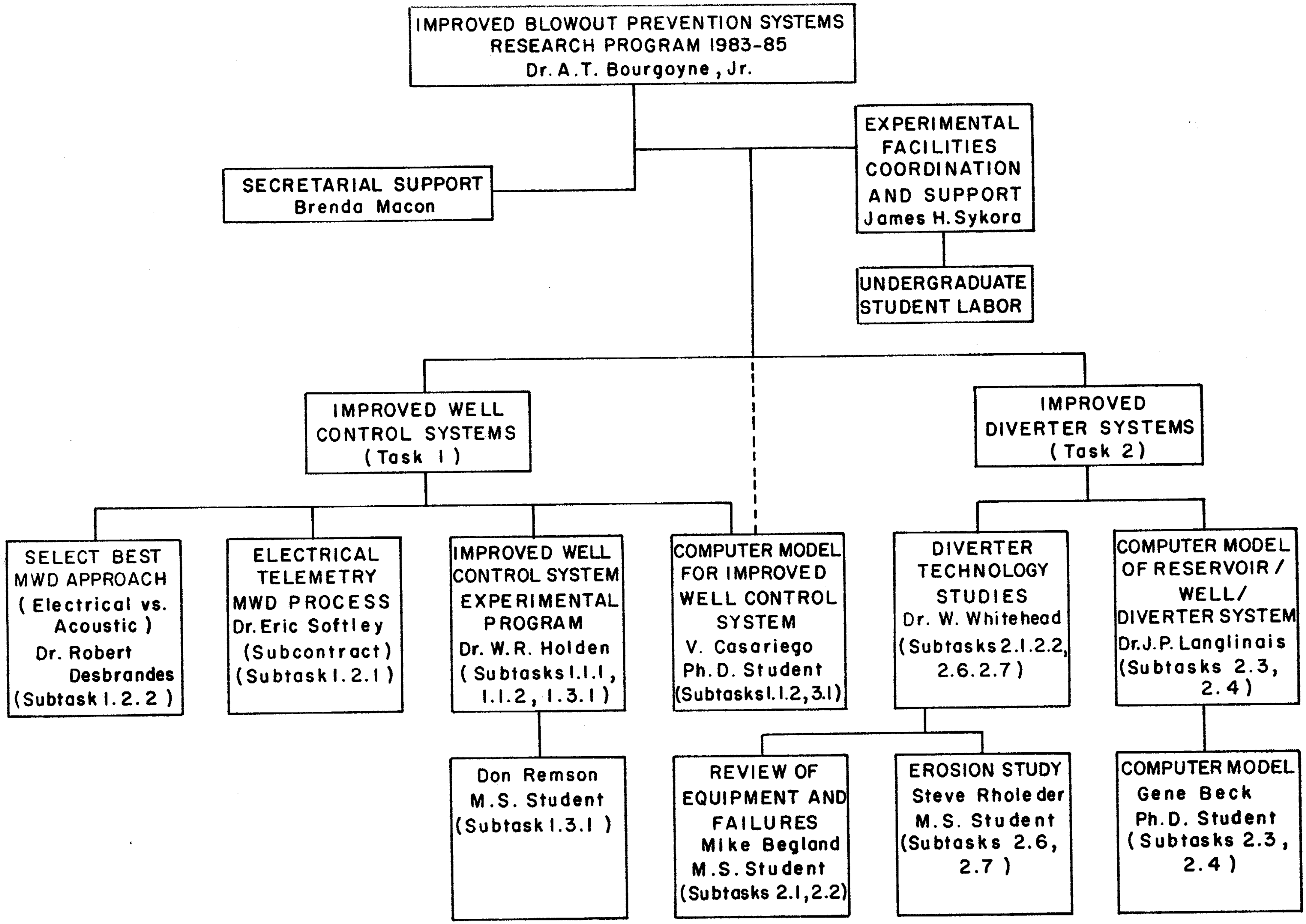

FIGURE 2. ORGANIZATIONAL STRUCTURE FOR CURRENT RESEARCH PROGRAM

facility and tested extensively for possible applications with M.W.D. technology. None of these currently available systems have proven to have the close tolerance control capabilities that are needed. The team is currently working on the development of a novel system which will have the required characteristics. The input/output sensors needed to measure and control the automated well control process are being developed and tested.

Mr. Vincente Casariego, a PhD student under the supervision of Dr. A. T. Bourgoyne, Jr. is working on computer models which will assist in the determination of data requirements for an overall well control strategy. Experimental work is also being done to assist in the development and verification of the computer model. Ultimately, the developed computer programs will permit an accurate prediction of the various well control parameters measured at the surface as a function of down hole kick conditions.

Dr. Eric Softley, of OEA, Inc. was subcontracted to perform a major portion of an evaluation of an electrical telemetry MWD process. This process was explored because of its potential for greatly increasing the rate of data transmission from the bottom of the hole to the surface. Tests of a scale model of the electrical telemetry MWD system have been completed, and this technique shows considerable promise. Work with Al Homes, of Harry Diamond laboratories, on a fluidic mud pulser is scheduled to begin soon.

The installation of a 10,000 ft. mud pulse flow loop at the LSU research well facility was completed in December. This installation will permit the study of any of the existing mud pulse data telemetry systems for safety related applications. Although considerable effort is being expended in the development of mud pulse telemetry systems, these tools are being developed primarily for use in directional drilling applications, formation evaluation applications, and drilling optimization applications.

A major problem anticipated in the use of existing commercial mud pulse telemetry tools for well control applications are their low data transmission rates. The fluidic mud pulser developed by Al Holmes, under sponsorship of the MMS research program, shows promise of a significantly increased data transmission rate over the existing commercial tools. Evaluation of the Al Holmes device is being done as part of Subtask 1.2.2.

A review of existing diverter technology, including both equipment and procedures (Subtask 1) is was conducted by Mr. Mike Begland, an M.S. student, under the supervision of Dr. W. R. Whitehead. In addition, a study of diverter failures (Subtask 2.2) was also being undertaken. Mr. Steve Rohleder, also an M.S. student, is assisting in the diverter failure study and also working on a study of the erosion and plugging failure mechanisms applicable to diverter systems (Subtask 2.6 and 2.7). Mr. Rohleder is also working under the supervision of Dr. W. R. Whitehead. This group has been working closely with MMS personnel in Metairie, La., and with offshore well operators in obtaining the needed information.

The development of a computer model of the reservoir, wellbore, diverter system (Subtask 2.3) is being done by Mr. Gene Beck, a Ph.D. student, under the supervision of Dr. J. P. Langlinais. The computer model, in conjunction with the other diverter studies, will eventually permit the development of improved diverter design and procedures.

The initial diverter studies has permitted the design of an almost full scale experimental diverter model. Recent expansions of the research and training well facility, including the installation of a $97,000, 6-in. gas pipeline connecting a large gas transmission pipeline to the facility, has made practical the implimentation of the diverter model design. Work on the model diverter system was began in late December and is now about 60 percent complete. It will be possible to study supersonic single and two phase flow conditions in the model diverter system.

Subtask 2.4 is the experimental verification of the computer model developed by Mr. Gene Beck and Dr. Langlinais in Subtask 2.3. The model diverter system will be utilized in this portion of the study. The model diverter system would employ diverter design concepts resulting from the diverter studies of Subtasks 2.1, 2.2, and 2.6. This model diverter system would be operated by utilizing the energy of stored compressed gas from the gas storage well. Two phase flow can be simulated by simultaneously displacing liquids from the buried drill pipe loop and gas from the storage well. By utilizing the total available volume from these high pressure systems, quite realistic diverter situations can be simulated. Also, the model diverter system is being constructed so that it could be easily modified to test different diverter arrangements and components. The model diverter system should also prove to be quite valuable in MMS mandated well control training activities.

Subtask 3.1 will involve the development and testing of improved methods for kick detection for floating drilling operations. Early detection is a key element in a successful well control program. Early kick detection is much more difficult for floating drilling operations because of vessel movement. Work on this subtask is scheduled to begin early this summer.

Plans for Phase III

Because of anticipated budgetary constraints, plans for the next phase of the research have been separated into several options and assigned a priority. A base plan for continuing the top priority work at a reduced level of activity will be presented first. Additional research activities which are also highly desirable, but having a lower priority will be summarized in this proposal. A more detailed presentation will be given later in separate proposals.

Recent expansions of the research and training well facility has made possible more extensive research on diverter systems than was originally anticipated. These expansions have been made possible by (1) state funds provided as part of a university quality thrust program in the earth sciences and (2) by grants from industry. As a result, two high priority tasks have been added to the diverter study. These tasks include Task (2.8), the experimental evaluation of alternative diverter designs, and Task (2.9), the study of the marine risers as part of the diverter system. The need for the last task was brough to light by a recent accident in the Gulf of Mexico Region which cost the lives of three people. Task (2.5), the study of the possible use of an optimal backpressure in certain cases of diverter operation, is also included in the top priority category.

Work on Task 1, the development of improved well control systems through the use of MWD and process control technologies has been assigned the second highest priority. Subtask 1.3.2, the development of the process control computer and computer logic, originally scheduled for the 1985-86 year is the most important aspect of this study. Extensions coming out of the work done in subtaks 1.2.1 on the evaluation of the electrical telemetry technique is given the third highest priority and potential additional work on the fluidic mud pulser is given the fourth highest priority.

It is recommended that implimentation of subtasks (3.2) and (5.1) originally scheduled for 1985-86 be delayed. It is felt that subtask (3.2), on pore pressure determination and kick detection assisted by MWD Technology, would be premature, due to a longer period needed to complete the MWD evaluation work. Task (5), dealing with upward gas migration in directional boreholes, is now being addressed by the Drilling Engineering Association, Inc. for work at LSU. It now appears likely that this task will be performed at our research center with industrial funding.

The organizational structure needed for the top priority research tasks is shown in Fig. 3. Lower costs can be achieved only through a reduction in the size of the current research team. Thus, Dr. Holden, Dr. Desbrandes, and Dr. Whitehead are not included in the 1985-86 top priority plan. However, proposals will follow showing how they could be involved in a continuation of Task 1, should funding become available.

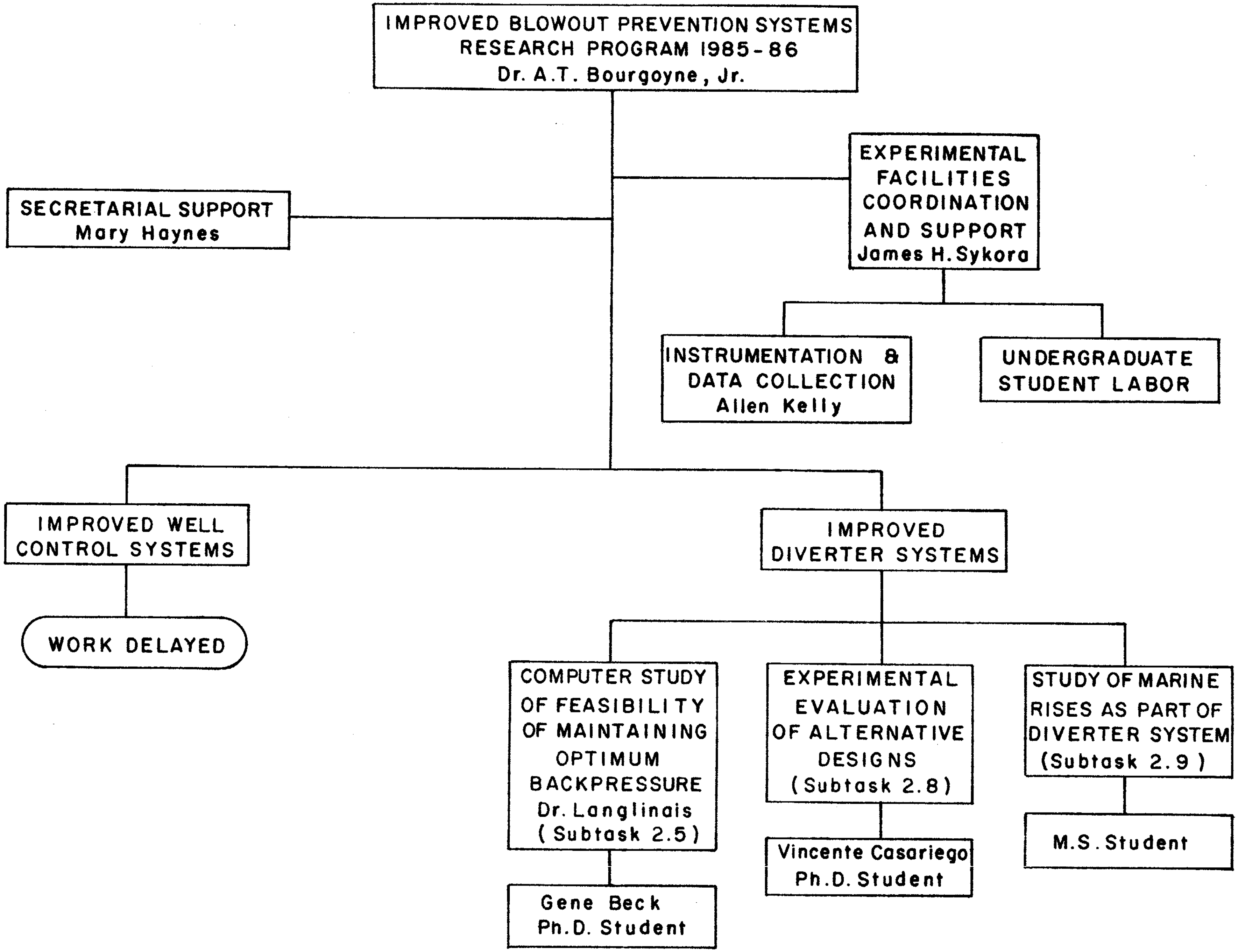

FIGURE 3. ORGANIZATIONAL STRUCTURE NEEDED FOR TOP PRIORITY RESEARCH AREAS, 1985-86

IV. BUDGET REQUIREMENTS FOR PHASE III

The budget requirements for the top priority portion of Phase III of the project are shown in Table 2. The total estimated cost for this work is $371,587.

An approximate breakdown of the cost of this work by task is given in Table 3.

TABLE 2

BUDGET FOR SUBTASKS

2.5, 2.8, 2.9

(Extends project through September 30, 1986)

1.	Direct Costs			
	a.	Principal Investigators (LSU)		
		(1)	Adam T. Bourgoyne, Jr., Ph.D., P.E. 6 man-months	38,000
		(2)	Julius P. Langlinais, Ph.D., P.E. 4.3 man-months	18,000
	b.	Supporting Personnel - Faculty		
		(1)	Jim Sykora, P.E. 10 man-months	29,000
		(2)	Allen Kelly, M.S., P.E. 10 man-months	25,000
	c.	Supporting Personnel - Clerical Mary Haynes 2.0 woman-months		4,000
			Faculty and Staff Subtotal	$114,000
	d.	Supporting Personnel - Graduate Students		
		(1)	Ph.D. Candidates 15.0 man-months	31,500
		(2)	M.S. Students 4.5 man-months	7,000
			Graduate Student Subtotal	$38,500
	e.	Supporting Personnel - Undergraduate Students 4000 man-hours		18,000
	f.	Services		
		(1)	Engineering Research Services	
		(a)	Machine Shop (70 hours)	1,000
		(b)	Welding (400 hours)	6,000

PROFESSIONAL RESUME

Adam T. (Ted) Bourgoyne, Jr.
Professor and Chairman
Petroleum Engineering Department
Louisiana State University
Baton Rouge, Louisiana 70803
Office Phone: 504-388-5215

PERSONAL INFORMATION

Born: July 1, 1944, Baton Rouge, Louisiana
Married: Kathryn Daspit of Baton Rouge, La., January 22, 1966
Children: Two girls and four boys
Home Address: 6006 Boone Drive
Baton Rouge, Louisiana 70808
Home Phone: 504-766-7507

EDUCATION

B.S. in Petroleum Engineering, Cum Laude, 1966
Louisiana State University

M.S. in Petroleum Engineering, 1967
Louisiana State University

Ph.D. in Petroleum Engineering, 1969
University of Texas at Austin

PROFESSIONAL EXPERIENCE SUMMARY

Industrial Experience

1. Mobil Oil Company; Opelousas, Louisiana
   Summer, 1963

   Title: Roustabout
   Supervisor: Plant Foreman
   Duties: Maintenance of plant equipment of gas cycling operations in Opelousas field.

2. Mobil Oil Company; Cameron, Louisiana
   Summer, 1964

   Title: Offshore Roustabout
   Supervisor: Production Foreman
   Duties: Installation of automation equipment on offshore production platforms.

3. Mobil Oil Company; Morgan City, Louisiana
Summer, 1965

Title: Assistant Production Engineer
Supervisor: District Production Engineer
Duties: Assisted with well workover planning and economic justification of well workovers.

4. Texaco, Inc.; Morgan City, Louisiana
Summer, 1966

Title: Assistant Drilling Engineer
Supervisor: District Drilling Engineer
Duties:
a) Assisted with well planning and cost estimates
b) Designed jet bit hydraulics programs for ongoing drilling operations
c) Assisted company representative in supervision of drilling operations

5. Chevron Oil Research Laboratory; LaHabra, California
Summer, 1967

Title: Reservoir Engineer
Supervisor: Reservoir Simulation Group Leader
Duties:
a) History Matching reservoir behavior using reservoir simulators (computer models)
b) Developing new programs for interpreting drill stem test data and well interference test data

6. Continental Oil Research Laboratory; Ponca City, Oklahoma
Summer, 1968

Title: Research Engineer
Supervisor: Enhanced Oil Recovery Group Leader
Duties: Experimental evaluation of a new surfactant system for enhanced oil recovery

7. Continental Oil Company; Houston, Texas
June, 1969 to December, 1970

Title: Senior Systems Engineer
Supervisor: Manager, Production Engineering Services Group
Duties: Computer applications in drilling and production. Work included drilling data acquisition, abnormal pressure detection, optimization of drilling hydraulics, optimization of bit weight and rotary speed, design of flowline networks involving simultaneous flow of gas and liquids, and design of submersible electric pump installations.

8. Bariod Division of N.L. Industries, Inc.; Houston, Texas
Summer, 1972

Title: Senior Research Engineer
Supervisor: Manager, Well Information Services and Engineering Group
Duties: Design of new computerized well monitoring unit for determining formation pressure while drilling

Academic Experience

1. University of Texas; Austin, Texas
September, 1968 to May, 1969

Title: Teaching Assistant
Supervisor: Chairman, Petroleum Engineering Department
Duties: Teaching undergraduate prtroleum engineering laboratory courses

2. Louisiana State University; Baton Rouge, Louisiana
December 10, 1970 to present

Titles: Assistant Professor
December 10, 1970 to August 22, 1974

Associate Professor
August 22, 1974 to May 22, 1977

Associate Professor and Chairman
May 22, 1977 to August 15, 1979

Professor and Chairman
August 15, 1979 to May 31, 1983

Campanile Professor
June 1, 1983 - Present

Duties:

a) Undergraduate Courses Taught

1) CSC 1241, FORTRAN Programming
2) PetE 2020, Introduction to Petroleum Engineering
3) PetE 3031, Reservoir Fluid Flow
4) PetE 3032, Phase Behavior of Hydrocarbon Systems
5) PetE 3033, Petrophysics Laboratory
6) PetE 3034, Phase Behavior Laboratory
7) PetE 3990, Undergraduate Special Projects
8) PetE 3035, Economic Aspects of Petroleum Production
9) PetE 4045, Drilling Engineering
10) PetE 4046, Well Design - Production
11) PetE 4051, Reservoir Engineering
12) PetE 4086, Advanced Drilling Engineering

b) Graduate Courses Taught

1) PetE 7201, Advanced Reservoir Engineering
2) PetE 7241, Advanced Drilling Fluid Rheology
3) PetE 7242, Risk Analysis in the Petroleum Industry
4) PetE 7256, Special Problems in Petroleum Engineering
5) PetE 8000, Thesis Research

c) Extension Courses Taught

PetE 4045, Drilling Engineering, USGS Office, Metairie, Louisiana, 1979-1980

d) Short Course Taught

Have participated extensively since 1971 as instructor in Blowout Control Training Center. Have also participated in Well Completion Short Courses and Drilling Engineering Practicum.

e) Committees

1) Departmental Graduate Program Committee, 1976-68
2) Engineering Self-Study Committee, 1969-70
3) Engineering Policy Committee, 1976-77
4) Engineering Student Affairs Committee, 1970-77 (Chairman, 1976-77)
5) Engineering Committee on Faculty Evaluations
6) University Commencement Exercise Committee, 1974-77
7) LWRRI Advisory Board, 1977-present

f) Grants and Contracts

1) "A Multiple Regression Approach to Optimal Drilling and Abnormal Pressure Detection," Bariod Division of N.L. Industries, Inc., $11,649, 1972-73.

2) "The Determination of Abnormal Formation Pressure Using a Computerized Mathematical Model of the Rotary Drilling Process," Bariod Division of N.L. Industries, Inc., $9,200, 1973-74.

3) "Experimental Research on New Surfactant Placement Techniques for Enhanced Recovery of Petroleum by Water Displacement," O. K. Kimbler, A. T. Bourgoyne, and W. R. Whitehead, $28,000, 1976-77.

4) "Development of Improved Laboratory and Field Procedures for Determining the Carrying Capacity of Drilling Fluids," Milchem, Incorporated, $12,071.83, 1977-78.

5) "Investigation of Enhanced Oil Recovery Through Use of Carbon Dioxide," W. R. Whitehead, O. K. Kimbler, W. R. Holden, and A. T. Bourgoyne, U.S. Department of Energy, $161,120, 1978-79.

6) "Technical Support for Geopressured Well Acitivites in Louisiana," Z. A. Bassiouni, W. J. Bernard, and A. T. Bourgoyne, $85,500, 1978-79.

7) "Development of Improved Blowout Prevention Procedures to be Used in Deepwater Drilling Operations," A. T. Bourgoyne, W. R. Holden, and B. R. Hise, U.S. Department of the Interior, $822,962, 1978-82.

8) "A proposal for the Expansion of the LSU-IADC Blowout Prevention Training Center," Various Companies in Petroleum Industry, $2,000,000, 1980-82.

9) "A Feasibility Study on the Integration of Measurements While Drilling (MWD) Technology and Well Control Technology," A. T. Bourgoyne and W. R. Holden, U.S. Minerals Management Service, $90,000, 1983.

g) Theses Directed

1) Mannarino, Remo: "The Effects of Sealing and Non-Sealing Faults on Pressure Build-Up and Pressure Draw-down Analysis" (August, 1971).

2) Lavaquial, Fernando P.: Water Influx Into Petroleum Reservoirs from Adjacent Shales" (August, 1971).

3) Rader, David W.: "Movement of Gas Slugs Through Newtonian and Non-Newtonian Liquids in Vertical Annuli" (May, 1973).

4) Simmons, Richard D.: "A Comparison of Horizontal Multiphase Flow Pressure Loss Correlations" (May, 1973).

5) McKenzie, Michael F.: "Factors Affecting Surface Casing Pressure During Well Control Operations" (August, 1974).

6) Ward, Robert H.: "Movement of Gas Slugs Through Static Liquids in Large Diameter Annuli" (August, 1974).

7) Koederitz, W. L.: "The Mechanics of Large Bubbles Rising in an Annulus" (May, 1976).

8) Mathews, Gerald L.: "A Microscopic Investigation of the Use of Preferentially Oil Soluble Surface Active Agents to Enhance Oil Recovery" (May, 1977).

9) Ofoh, Ebere Paulinus: "The Effect of Flood Rate on Displacement Efficiency When Using Oil Soluble Surface Active Agents to Enhance Oil Recovery" (May, 1978).

10) Sample, Kenneth John: "Development of Improved Procedures for Determining the Carrying Capacity of Drilling Fluids" (August, 1978).

11) Bizanti, Mohamed: "New Bit Designs for Reducing Bottom Hole Pressure While Drilling" (December, 1978).

12) Mathews, Jeffrey L.: "Upward Migration of Gas Kicks in a Shut-in Well" (May, 1980).

13) Casariego, Vicente G.: "Experimental Study of Two Phase Flow Patterns Occurring in a Well During Pressure Control Operations" (May, 1981).

14) Redmann, Kerry P.: "Flow Characteristics of Commercially Available Drilling Chokes Used In Well Control Operations" (May, 1982).

PROFESSIONAL SOCIETIES AND ACTIVITIES

1. Registered Profession Engineer (Petroleum) in Louisiana, No. 15776

2. AIME-SPE (Presently charged with writing SPE sponsored textbook on drilling, also serving as Chairman of the Engineering Manpower Committee)

3. API (Presently serving on national committee concerning the determination of formation pore pressures and fracture gradients)

4. ABET (Presently serving on Education and Accreditation Committee and serving on adhoc visiting committee)

5. Minerals Management Service (Conducted Well Control Research Workshop to recommend long range research plan for research program of MMS, March 26, 1982)

HONORARY SOCIETIES AND AWARDS

1. Tau Beta Pi

2. Pi Epsilon Tau

3. SPE Distinguished Achievement Award for Petroleum Engineering Faculty, 1981

CONSULTING ACTIVITIES

1. Continental Oil Company, Drilling Data Acquisition Project, 1971

2. Mobil Oil company, Computer Assisted Design of Jet Bits, 1973

3. Bariod Division of N. L. Industries, Automated Mud Logging Service, 1973-76

4. Department of Commerce, National Bureau of Standards, Energy Patent Evaluator, 1977-1981

5. Grumman Houston Corporation, Automated Well Logging System Evaluation, 1977-78

6. Otis Engineering Corporation, Well Control Technology Advisor, 1978-present

7. Superior Oil Company, Drilling Cost Analysis, 1980-81

8. Wemco Division of Envirotec Corporation, Expert witness in Patent Infringement suit, 1982-83

PUBLICATIONS

a. Refereed Journal Articles:

1) "Number Simulation of Drillstem Tests as an Interpretation Technique," J. P. Brill, A. T. Bourgoyne, and T. N. Dixon, Journal of Petroleum Technology (Nov., 1969).

2) "The Effect of Interfacial Films on the Displacement Efficiency of a Waterflood," Transactions, AIME (1971).

3) "A Multiple Regression Approach to Optimal Drilling and Abnormal Pressure Detection," A. T. Bourgoyne and F. S. Young, Transactions, AIME (1974).

4) "Factors Affecting Bubble Rise Velocity of Gas Kicks," D. W. Rader, A. T. Bourgoyne and R. E. Ward, Journal of Petroleum Technology (May, 1975).

5) "A Feasibility Study on the Use of Subsea Chokes in Well Control Operations on Floating Drilling Vessels," J. L. Mathews and A. T. Bourgoyne, Journal of Petroleum Technology (May, 1982) and Transactions, Society of Petroleum Engineers, 1982.

6) "An Experimental Evaluation of Correlations Used for Predicting Cutting Slip Velocity," K. J. Sample and A. T. Bourgoyne, Scheduled for publication in Journal of Petroleum Technology.

7) "Development of Improved Laboratory and Field Procedures for Determining the Carrying Capacity of Drilling Fluids," K. J. Sample and A. T. Bourgoyne, SPE 7494, Presented at the 53rd Annual Fall Meeting of Society of Petroleum Engineers; Houston, Texas (Oct., 1978), Scheduled for publication in Journal of Petroleum Technology.

8) "Frictional Pressure Losses for Single Phase and Two-Phase Flow of Drilling Muds", F. Elfaghi, J. P. Langlinais, A. T. Bourgoyne, and W. R. Holden,Journal of Energy Resources Technology (Sept. 1983).

b. Books and Chapters of Books:

1) "Drilling Practices," A Chapter in Encyclopedia of Chemical Processing and Design, Vol. 16, Edited by John J. Mcketta and

William A. Cunningham, Marcel Dekker, Inc., New York, N.Y. 10016 (1982).

2) Applied Drilling Engineering, A. T. Bourgoyne and F. S. Young, Society of Petroleum Engineers of AIME, Dallas, Texas 75206 (accepted for publication by SPE textbook committee).

3) "Complications and Special Well Control Techniques," LSU/IADC Blowout Prevention Manual, Chapter 12, LSU Blowout Prevention School; Baton Rouge, Louisiana (Nov., 1978).

c. Conference Proceedings:

1) "A Critical Examination of Rotary Drilling Hydraulics," Proceedings of Second SPE Conference on Drilling and Rock Mechanics; Austin, Texas (Jan., 1968).

2) "Water Influx into Petroleum Reservoirs from Adjacent Shales," Proceedings of Third SPE Symposium on Abnormal Pressure; Baton Rouge, Louisiana (May, 1972).

3) "Multiple Regression Approach to Optimal Drilling and Abnormal Pressure Detection," A. T. Bourgoyne and F. S. Young, Proceedings of Sixth SPE Conference on Drilling and Rock Mechanics; Austin, Texas (Jan., 1973).

4) "The Use of Drillability Logs for Formation Evaluation and Abnormal Pressure Detection," A. T. Bourgoyne and F. S. Young, Proceedings of SPWLA Fourteenth Annual Logging Symposium; Lafayette, Louisiana (May, 1973).

5) "A University View of the Status and Future of Petroleum Engineering Education," Proceedings of the First Annual Engineering Manpower Conference of SPE; Houston, Texas (June, 1978).

6) "The Dynamics of Well Control," Proceedings of the Second Research and Development Conference for OCS Oil and Gas Operations; Reston, Virginia (April, 1980).

7) "Development of Improved Blowout Prevention Procedures for Deepwater Drilling Operations," Proceedings of the Third Research and Development Conference for OCS Oil and Gas Operations; Reston, Virginia (November, 1981).

8) An Experimental Study of Well Control Procedures For Deep Water Drilling Operations," W. R. Holden and A. T. Bourgoyne, Proceedings of Offshore Technology Conference, Houston, Texas (May, 1982).

9) "Techniques for Handling Upward Migration of Gas Kicks in a Shut-in Well," J. L. Mathews and A. T. Bourgoyne, SPE/IADC Drilling Conference, New Orleans, La. (Feb. 20-23, 1983).

d. Trade Journal Articles:

1) "Simplified Drilling Hydraulics," World Oil (Jan., 1969).

2) "Computer Graphics Improve Drilling Hydraulics," A. T. Bourgoyne and R. E. McKee, Petroleum Engineer (Sept., 1970).

3) "Porosity and Pore Pressure Logs," A. T. Bourgoyne, J. A. Rizer and G. M. Myers, The Drilling Contractor (June, 1971).

4) "A New Approach to Overpressure Detection While Drilling," Petroleum Engineer (Sept., 1971).

5) "Graphic Approach to Kick Severity Calculations," Petroleum Engineer (Sept., 1976).

8) "Well Control Procedures for Deepwater Drilling--Part 1," A. T. Bourgoyne, W. R. Holden, B. R. Hise and R. S. Sullins, Ocean Resources Engineering (April, 1978).

9) "Well Control Procedures for Deepwater Drilling--Part 2: Control of Shallow Kicks," A. T. Bourgoyne, W. R. Holden, B. R. Hise, and R. S. Sullins, Ocean Resources Engineering (Oct., 1978).

20) "Well Control Procedures for Deepwater Drilling--Part 3: Initiation of Well Control Operations," A. T. Bourgoyne, W. R. Holden, B. R. Hise, and R. S. Sullins, Ocean Resources Engineering (Dec., 1978).

11) "University Uses On-Campus Abandoned Well to Simulate Deep Water Well Control Operations," Oil and Gas Journal (May 31, 1982), 138-141.

e. Selected Reports

1) "Final Report of College of Engineering Self-Study Committee," P. H. Miller, A. T. Bourgoyne, B. J. Covington, C. E. Hall, D. P. Harrison, E. C. Tacker, and D. W. Yannitell, Louisiana State University (March, 1972).

2) "A Critical Examination of the Graduate Program in Petroleum Engineering at Louisiana State University" (March, 1977).

3) "Department of Petroleum Engineering Five Year Plan" (Feb., 1978).

4) "Department of Petroleum Engineering, Five Year Plan 1982-87" (Sept. 1982).

PROFESSIONAL RESUME

Julius Patrick Langlinais
Assistant Professor
Petroleum Engineering Department
Louisiana State University
Baotn Rouge, Louisiana 70803
Office Phone: 504-388-5215

PERSONAL INFORMATION

Born: September 5, 1945, New Iberia, Louisiana
Married: Betty Musumeche of New Iberia, La., November 26, 1966
Children: Two girls
Home Address: 968 Bromley Drive
Baton Rouge, Louisiana 70808
Home Phone: 504-766-0203

EDUCATION

B.S. in Physics (With Distinction), 1967
University of Southwestern Louisiana

M.S. in Physics, 1970
Louisiana State University

Ph.D. in Physics, 1971
Louisiana State University

PROFESSIONAL EXPERIENCE

Industrial Experience

1. Construction Company, New Iberia, Louisiana
   Summer, 1963

   Title: Laborer
   Supervisor: Foreman
   Duties: Construction Labor

2. Central Louisiana Electric Company, New Iberia, Louisiana
   Summer, 1964 and Summer, 1966

   Title: Shop Helper
   Supervisor: District Engineer
   Duties: Transformer maintenance and repair

3. Grisby Brothers, New Iberia, Louisiana
   Summer, 1965

   Title: Offshore Roustabout
   Supervisor: Foreman
   Duties: Platform sandblasting and painting crew

4. E. I. DuPont Company, Aiken, South Carolina
   Summer, 1967

   Title: Summer Assistant
   Supervisor: Director of Theoretical Physics Group
   Duties: Computer applications in Nuclear Reactor loading

5. Continental Oil Company, New Orleans, Louisiana
   July, 1975 to March, 1978

   Title: Production Engineer and Reservoir Engineer
   Supervisor: District Engineer
   Duties: Surface and subsurface aspects of offshore production engineering, including compressor installation, gas lift design, workover operations, and others. Reservoir included economic appraisal, reservoir studies, open hole logging and others.

6. Superior Oil Company, Lafayette, Louisiana
   March, 1978 to August, 1980

   Title: Production Engineer and Drilling Engineer
   Supervisor: District Engineer
   Duties: Production included various aspects of that area, specifically in inland waters and land operations. Drilling included cost estimates, well design, pressure detection and general activities of that area.

Academic Experience

1. University of Southwestern Louisiana, Lafayette, Louisiana
   January, 1966 to May, 1967

   Title: Laboratory Instructor
   Supervisor: Chairman, Physics Department
   Duties: Teaching undergraduate Physics labs

2. Louisiana State University, Baton Rouge, Louisiana
   September, 1967 to May, 1968

   Title: Teaching Assistant
   Supervisor: Chairman, Physics Department
   Duties: Teaching senior-level Modern Physics Laboratory

3. Louisiana State University, Baton Rouge, Louisiana
   June, 1968 to August, 1971

   Title: NDEA Fellowship Recipient
   Supervisor: Chairman, Physics Department
   Duties: Research fellowship culiminating in Ph.D. degree

4. University of Tampa, Tampa, Florida
September, 1971 to May, 1975

Title: Assistant and Associate Professor of Physics and Mathematics
Supervisor: Dean of the Faculty
Duties: Teach courses in undergraduate Mathematics (Calculus, Complex Variables, Computer programming) and Physics (Introductory Physics, Optics, Electronics).

5. Louisiana State University, Baton Rouge, Louisiana
August, 1980 to present

Title: Assistant Professor
Supervisor: Chairman, Petroleum Engineering Department

Duties:

a) Undergraduate Courses Taught

1) PetE 3035, Economic Aspects of Petroleum Production
2) PetE 3033, Petrophysics Laboratory
3) PetE 3031, Petrophysics
4) PetE 4045, Drilling
5) PetE 4046, Well Design-Production

b) Graduate Courses Taught

1) PetE 7242, Selected Topics in Production Engineering

c) Extension Courses Taught

1) PetE 3035, Economic Aspects of Petroleum Production USGS, Metairie, Louisiana - 1980

d) Short Courses Taught

Have been involved as instructor in Blowout Control Training Center since Spring, 1981.

e) Committees

1) College of Engineering Scholarship Committee
2) Organization Relief Fund (Student Affairs) Committee

f) Grants and Contracts

1) "Waste Disposal Well Integrity Testing and Formation Pressure Build-up Study," Louisiana Department of Natural Resources, $30,587.00, 1981.

g) Thesis Directed

1) Surcoff, Robert M., Jr.: "An Examination of Blowout Prevention Equipment and Procedures Used on Floating Vessels" (Dec, 1981).

2) Elfaghi, Fawzi A.: "Pressure Losses in Subsea Choke Lines During Well Control Operations" (May, 1982).

3) Wilcox, Terry C.: "Mechanical Integrity Testing of Injection Wells" (Aug., 1982).

PROFESSIONAL SOCIETIES AND ACTIVITIES

1. Registered Professional Engineer (Petroleum) in Louisiana, No. 17000

2. AIME - Society of Petroleum Engineers

3. Sigma Pi Sigma (Physcis)

4. Kappa Mu Epsilon (Math)

5. Phi Kappa Phi

CONSULTING ACTIVITIES

1. Superior Oil Company, Drilling Cost Analysis, 1980 to present

2. Louisiana Department of Natural Resources, 1981 to present

PUBLICATIONS

a. Refereed Journal Articles

1) "Energy Bands in Nickel Using the Tight Binding Method," Callaway, Zhang, Norwood and Langlinais, International Journal of Quantum Chemistry, 4, 425 (1971).

2) "Energy Bands in Ferromagnetic Nickel," Langlinais and Callaway, Physical Review B., Vol. 5, No. 1, 124-134 (1972).

3) "Frictional Pressure Losses for Single Phase and Two-Phase Flow of Drilling Muds," Fawzi, Langlinais, Bourgoyne and Holden, Journal of Energy Resources Technology (to be published - September 1983).

b. Trade Journal Articles

1) "Economical Recompletion to a Pay Sand Above the Top Packer," J. Langlinais and P. Brazan, Continental Oil Company Monthly Engineering Letter (May, 1976).

2) "Deep Gas Lift Using Packoff Valves," J. Langinais, Continental Oil Company Monthly Engineering Letter (January, 1977).

c. Reports

1) "Waste Dsposal Well Integrity Testing and Formation Pressure Build-Up," submitted to La. Dept. of Natural Resources (Sept., 1981).

2) "Enhanced Gas Recovery from Reservoirs with Associated Aquifers," Bourgoyne, A. T., Jr., Bernard, W. J., Bassiouni, Z. A., and Langlinais, J. P., submitted to LSU Energy Programs Office (April, 1982).

d. Conferences

1) "Energy Bands in Ferromagnetic Nickel," paper presented at the annual meeting of the American Institute of Physics (March, 1971).

Priority Two

BUDGET PLANNING UPDATE

for

MMS Contract 14-08-001-21169, Mod. 3
(LSU Project No. 127-45-5115)

on

THE DEVELOPMENT OF IMPROVED BLOWOUT PREVENTION SYSTEMS FOR OFFSHORE DRILLING OPERATIONS

Submitted to
The Minerals Management Service
United States Department of the Interior
Reston, Virginia

by
Petroleum Engineering Department
Louisiana State University

February, 1985

Priority Two

BUDGET PLANNING UPDATE

for

MMS Contract 14-08-001-21169, Mod. 3
(LSU Project No. 127-45-5115)

on

THE DEVELOPMENT OF IMPROVED BLOWOUT PREVENTION SYSTEMS FOR OFFSHORE DRILLING OPERATIONS

Submitted to
The Minerals Management Service
United States Department of the Interior
Reston, Virginia

by

Adam T Bourgoyne Jr

Adam T. Bourgoyne, Jr.
Principal Investigator

Wm R. Holden

William R. Holden
Co-Principal Investigator

Robert Desbrandes
Co-Principal Investigator

Board of Supervisors
of
LOUISIANA STATE UNIVERSITY

CONTENTS

I. INTRODUCTION

The Petroleum Engineering department at LSU has played an active role over the past decade in well control research and in training of industry personnel in present-day methods of well control. With the help of both industry and government modern training and research facilities centered around two 6000 ft wells were equipped to model well control operations conducted both in the shallow water marine environment of the continental slope and in deepwater offshore operations. A three million dollar expansion of this facility was recently achieved through the combined support of a consortium of 60 companies in the petroleum industry and through a research grant funded by the U. S. Minerals Management Service (MMS).

On March 24, 1982, a workshop was conducted at LSU to assist in the formulation of a long range plan for future well control research. The participants included (1) members of the industry advisory panel to the LSU Blowout Prevention Research Center (2) researchers currently being supported by MMS, and (3) representatives of various MMS districts. Twenty-one desirable projects were identified by this group. The top ten projects are listed in Table 1 along with a composite priority level assigned by the workshop panel.

A five year research plan was made in a proposal to MMS for developing improved well control systems for deep water offshore drilling operations. The proposed five year plan incorporates many of the high priority items identified at the LSU Well Control Workshop. In October, 1983, MMS Contract No. 14-12-001-21169, Mod. 2 was issued for LSU to

Table 1 - Recommendations made at March 24, 1982 LSU Well Control Workshop

Priority Level	Research Area	Votes Received Assuming Funding For following number of projects: One,	Two,	Three,	Four,	or Five
1	Feasibility Study on Use of MWD Technology in Well Control Operations on Floating Vessels	<u>6</u>	9	9	19	11
2	Study of Well Control Operations with Simultaneous Formation Fracture	3	<u>10</u>	12	16	17
3	Well Control Operations for Short Casing Strings (Diverter Systems)	3	5	<u>8</u>	12	14
4	Improved Procedures for Handling Upward Gas Migration during stripping or Snubbing Operations	1	3	5	<u>5</u>	8
5	Improved System for Detecting Gas in Mud at Depth (as opposed to present surface detectors)	2	3	5	5	<u>7</u>
6	Study of Upward Gas Migration in Slant (Directional) Boreholes	1	2	3	5	7
7	Scale-up of Fluidic Pulse Telemetry System to longer systems with varying mud properties	0	1	3	4	5
8	Determination of Minimum Number of Requisite Parameters via MWD for safe drilling operations	1	1	1	3	5
9	Scale-up on Ongoing Fire Suppression System Development for Offshore Drilling	2	3	3	4	4
10	Study of Potential Problems due to Gas Hydrate Formation in Subsea Well Control Equipment in Deep Water	0	3	4	4	4

begin work on the first year of the five year plan. In October, 1984, the second year of the proposed plan was funded. Because of anticipated budgetary problems in continuing all aspects of the research program, the request for next years funds has been broken into various subcategories according to a recommended priority system. In early January, 1985 a priority one budget planning update was submitted. In this previously submitted document, the progress which has been made was summarized, and a budget update is provided for maintaining only the top priority research tasks of the project through the third year. Now in this proposals, the funding requirements needed to continue the other portions of the project are presented. These tasks are viewed as highly desirable and show good promise for success, but have a slightly lower priority than the items addressed in the previous proposal. Also the cost figures are incremental costs derived assuming that the previously submitted top priority items are funded. The work proposed here could not be done at the cost level given for stand-alone projects.

II. GENERAL RESEARCH PROGRAM OBJECTIVES AND TIMETABLE

The primary objective of the research project is to increase the efficiency and safety of offshore drilling operations. This would be accomplished through the development of improved blowout prevention systems. The two main systems included in the study are (1) the high pressure emergency circulating system and choke used to circulate formation fluids from a well under pressure, and (2) the diverter system which must be employed prior to setting sufficient casing to allow use of the high pressure system. Additional objectives deal with improved kick detection systems and complications that can develop as a result of formation fracture, directional drilling operations, or off-bottom kicks.

The overall research plan can be divided into six overall tasks. Several of these tasks can be subdivided into a number of subtasks. These tasks and subtasks are:

Task	Subtask	Description
1		Development of an improved blowout prevention system through the integration of measurements while drilling (MWD) and well control technologies.
	1.1	Determine the data requirements (parameters and speed of transmission) for automated well control system.
	1.1.1	Experimental study, (without secondary kicks) of parameters needed, time urgency, accuracy requirements, redundancy requirements, and trade offs.
	1.1.2	Determination of additional data requirements for overall well control strategy including surface data.

Task	Subtask	Description
	1.2	Selection of MWD System compatible with well control application.
	1.2.1	Evaluate electrical telemetry technique as high data rate alternative to conventional mud pulse telemetry.
	1.2.2	Select best available MWD approach.
	1.2.3	Extended Study of MWD Techniques.
	1.3	Engineering development of improved Blowout Prevention System.
	1.3.1	Define and develop appropriate new hardware for control of system.
	1.3.2	Develop Process Control Computer and computer logic.
	1.3.3	Integrate Process Control Computer into Well Control System.
	1.3.4	Experimental verification of Process Control Computer logic with risk of secondary kicks included in experimental programs.
2		Development of improved Diverter System for offshore operations.
	2.1	Review of available technology and current field practices on design and use of diverters on offshore drilling rigs.
	2.2	Review failures and cause of failures that have occurred in offshore diverter systems.
	2.3	Use of systems analysis approach to develop computer model of reservoir/well/diverter system.
	2.4	Experimental verification of computer model with scaled model of diverter system.
	2.5	Computer study of feasibility of maintaining an optimal backpressure during operation of diverter system.
	2.6	Literature and experimental study of erosion reduction techniques in diverter system (including bends).

Task	Subtask	Description
	2.7	Experimental and computer study of diverter plugging by produced solids.
	2.8	Experimental evaluation of alternative diverter designs.
	2.9	Study of marine riser as part of diverter system.
	2.10	Design of improved diverter systems for bottom supported rigs and floating drilling vessels.
3		Development of improved system for kick detection for floating drilling vessels.
	3.1	Improved surface and near surface kick detection system for floating drilling operation.
	3.2	Pore pressure determination and kick detection assisted by MWD technology.
4		Study of well control with simultaneous formation fracture.
	4.1	Development of computer model.
	4.2	Experimental verification of computer model.
	4.3	Computer study to identify cases where well control with simultaneous formation fracture are feasible or even beneficial.
5		Study of upward gas migration in slant (directional) boreholes.
	5.1	Experimental study.
	5.2	Development of computer model.
6		Development of improved blowout prevention system for off-bottom kicks.
	6.1	Development of computer model.
	6.2	Use of computer model to develop improved technique for handling upward gas migration during stripping operations.
	6.3	Use of computer model to evaluate multistage off-bottom kill procedure.

An updated timetable for accomplishing the general research program is shown in Figure 1. The current year funding (1984-85), for subtasks 1.2.2, 1.3.1, and 2.4, 2.7 and 3.1, was approved and is effective through September 30, 1985.

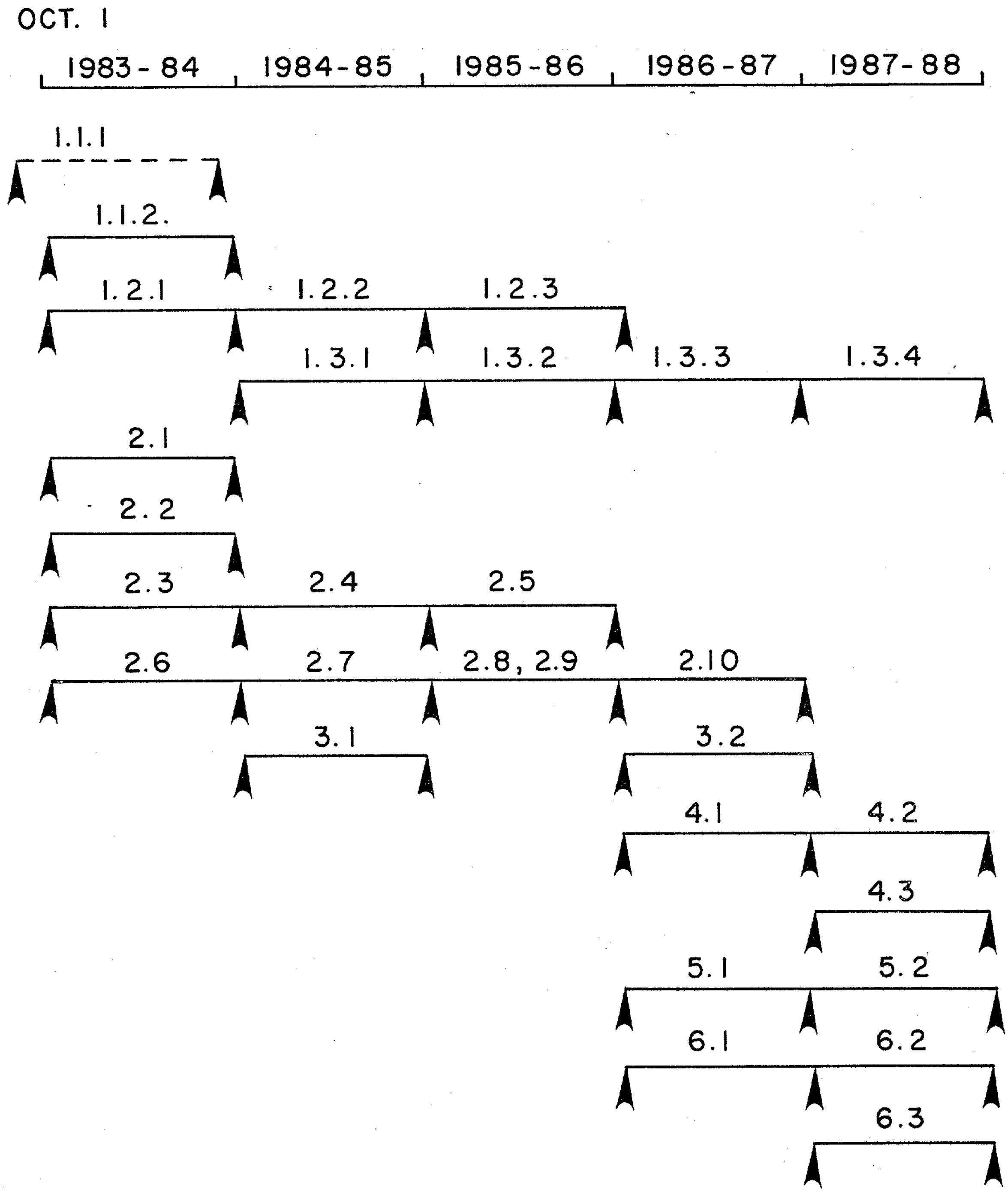

FIGURE 1. RESEARCH TIMETABLE

III. PROPOSED PROJECTS

The research effort to date has been directed into two major blowout prevention areas. The first area (Task 1) includes improved well control systems used for circulating out a kick under pressure. The second area (Task 2) includes improved diverter systems, which must be employed prior to setting sufficient casing to allow use of the high pressure well control system. A third area, dealing with improved kick detection systems, has also been initiated.

Plans for Phase III

Because of anticipated budgetary constraints, plans for the next phase of the research have been separated into several options and assigned a priority. A base plan for continuing the top priority work at a reduced level of activity has already been presented. Additional research activities which are also highly desirable, but having a lower priority will be presented in this proposal.

Work on Task 1, the development of improved well control systems through the use of MWD and process control technologies has been assigned the second highest priority. Subtask 1.3.2, the development of the process control computer and computer logic, originally scheduled for the 1985-86 year is the most important aspect of this study. Subtask 1.2.3 includes additional work extending the work done in subtaks 1.2.1 on the evaluation of the electrical telemetry technique and additional work on the fluidic mud pulser. This subtasks is given the third highest priority.

The organizational structure needed for adding subtask 1.3.2 and subtask 1.2.3 to the top priority research tasks is shown in Fig. 3.

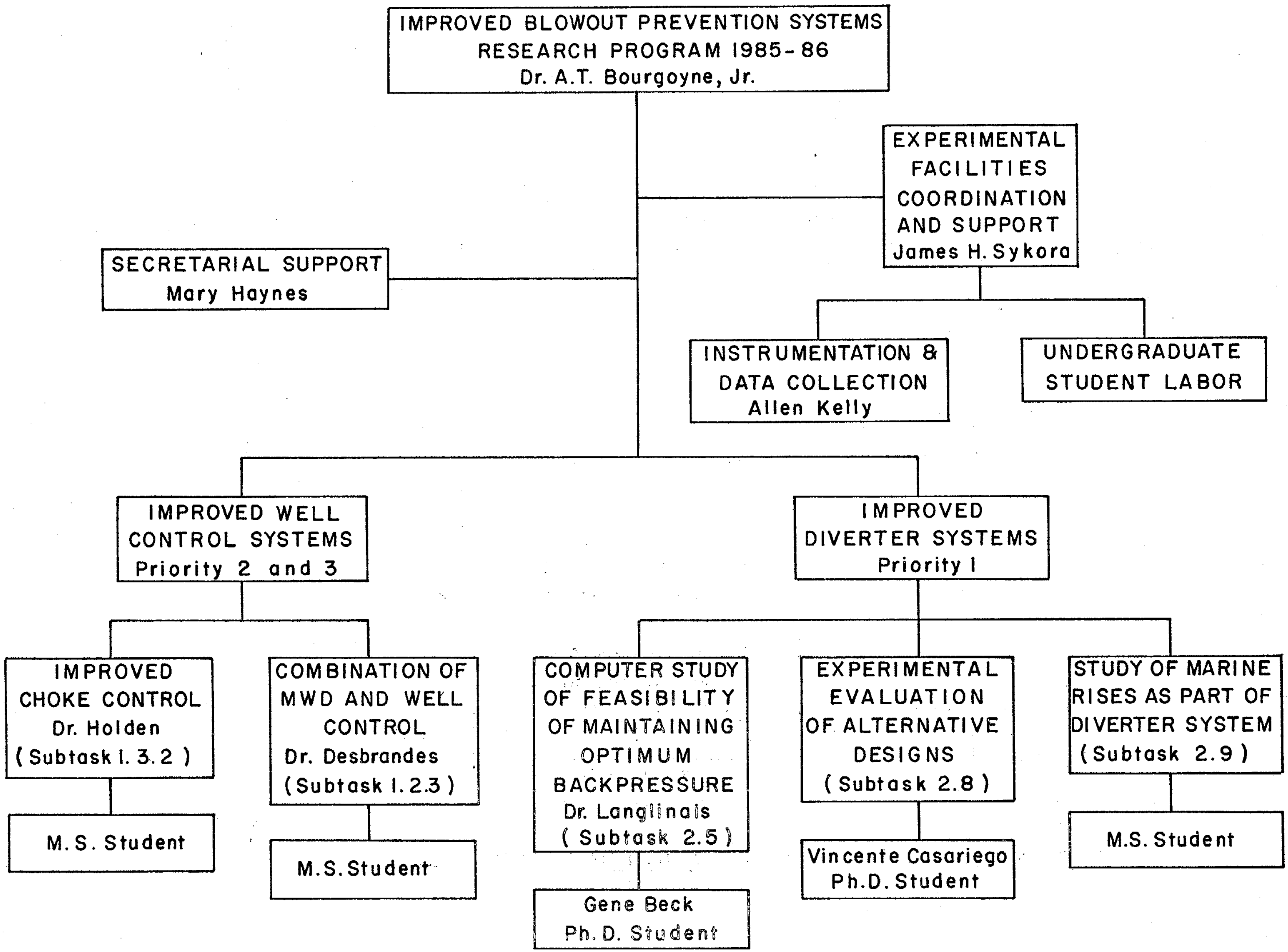

FIGURE 2. ORGANIZATIONAL STRUCTURE NEEDED FOR ALL RESEARCH AREAS, 1985-86

The equipment needed to evaluate different process control algorithms under varying well control conditions will be in place by the end of this fiscal year. In subtask 1.3.2, Dr. Holden would supervise the evaluation of different process control algorithms for reducing the pressure fluxuations experienced when circulating out a kick. This would be done by placing gas kicks in the LSU B-7 research well, and then pumping out the kick under computer control while monitoring pressures at several points in the system. It is envisioned that many experiments would be necessary to perfect the process control algorithms needed for the various choke designs. Preliminary work indicates that the different choke designs will require different control techniques. Once successfully completed, the choke operator would have a much greater chance of pumping out a kick successfully in one circulation with a reduced risk of fracturing a subsurface strata and causing an underground blowout.

Subtask 1.2.3, would be a continuation of the development of the use of MWD technology for safety related applications. This work would be done under the supervision of Dr. Desbrandes. A portion of the work would be subcontracted to OEA, Inc. as proposed in Appendix B. This subcontract work would be a continuation of subcontrack work started by Dr. Softley of OEA, Inc., in 1983, based on several novel ideas which he had proposed. Dr. Softley would focus his efforts on developing an electronics and computer package for installation at LSU where the experiments would be performed. Dr. Desbrandes would also oversee these experiments as well as begin work on the problems associated with insulating the drill string.

IV. BUDGET REQUIREMENTS FOR PHASE III

The budget requirements for the second and third priority items of Phase III of the project are shown in Table 2 and Table 3. The total estimated cost for this work is \$188,918.

TABLE 2

BUDGET FOR SUBTASK 1.3.2

Develop Process Control Computer and Computer Logic

(Priority 2)

1.	Direct Costs	
	a. Principal Investigators William R. Holden 3 man-months	18,000
	b. Supporting Personnel M.S. Student 4.5 man months	7,000
	c. Supplies Misc. Computer Electronics	3,000
2.	Fringe Benefits (18% of Faculty and Staff Subtotal)	3,240
3.	Indirect Costs MTDC, 31,240 (39% of MTDC)	12,184
4.	Tuition Remission (17% of Graduate Student Subtotal)	1,190
	Total	$44,614

TABLE 3

BUDGET FOR SUBTASK 1.2.3

(Priority 3)

1.	Direct Costs	
	a. Principal Investigators Robert Desbrandes 3.2 man months	20,000
	b. Supporting Personnel M.S. Student 4.5 man months	7,000
	c. Supplies and Services	
	(1) 4-Joints Drill-Pipe	N/C
	(2) Internal Coating of Drill-Pipe	10,000
	(3) Tool Joint Modifications	8,000
	(4) Misc.	4,000
	Subtotal	$22,000
2.	Fringe Benefits (18% of Faculty and Staff Subtotal)	3,600
3.	Indirect Costs MTDC, 52,600 (39% of MTDC)	20,514
4.	Tuition Remission (17% of Graduate Student Subtotal)	1,190
	Subtotal	$ 74,304
5.	Continuation of Subcontract to OEA, Inc.[1,2]	70,000
		$144,304

[1]Continuation subcontract to OEA documented in Appendix B.

[2]Indirect Costs for OEA subcontract charged in previous year.

APPENDIX A

Resume's of Key Personnel

PROFESSIONAL RESUME

William R. Holden
Professor
Petroleum Engineering Department
Louisiana State University
Baton Rouge, Louisiana 70803
Office Phone: 504-388-5215

PERSONAL INFORMATION

Born: December 20, 1928, Fort Worth, Texas
Married: Barbara Ann Babin, 1957
Children: Two daughters
Home Address: 2066 Columbine
Baton Rouge, Louisiana 70808
Home Phone: 504-766-2515

EDUCATION

B.S. Engineering Physics, 1953
University of Oklahoma

M.S. Engineering Physics, 1957
University of Oklahoma

Ph.D. Petroleum Engineering, 1969
University of Texas

PROFESSIONAL EXPERIENCE SUMMARY

Industrial Experience

Related Experience

1. 1977 - Invited speaker for international workshop on: "Management and Control of Oil Blowouts in the North Sea," sponsored by International Institute for Applied Systems Analysis (IIASA), Laxenburgh, Austria.

2. 1974 - Special lecturer for the international symposium: "Second Meeting on Porous Media Flow," Rio Claro (Sao Paulo), Brazil.

   Invited guest lecturer at Research and Development Center of Petrobras, Rio de Janeiro, Brazil.

3. 1973 - Special lecturer in Reservoir Engineering School for Texaco, Inc.

4. 1969 and 1970 - Special lecturer in Reservoir Engineering School for Mobil Oil Company.

5. 1969 - Invited guest at NATO sponsored seminar: "Hydrocarbon Reservoir Simulation by Computers," Milan, Italy.

6. Summers

    1) 1958 - Offshore Service Engineer, Salt Water Control, Inc. New Orleans, Louisiana.

    2) 1957 - Drilling Engineer, The California Co., Venice, Louisiana.

    3) 1956 - Production Engineer, The California Co., Brookhaven, Mississippi.

    4) 1954 - Engineer II, Linde Air Products Co., Tonawanda, New York.

    5) 1952 - Engineering Aid, GS-4, Development and Proof Services Branch, Aberdeen Proving Grounds, Maryland.

Academic Experience

1. Louisiana State University, Baton Rouge, Louisiana
September 13, 1955 to present

Titles: Assistant Professor
September 13, 1955 to September 11, 1963

Associate Professor
September 12, 1963 to August 22, 1973

Professor
August 23, 1973 to present

Duties:

a) Undergraduate Courses Taught

1) ENGR 2060, FORTRAN programming
2) PetE 3031, Petrophysics
3) PetE 3032, Phase Behavior of Hydrocarbon Systems
4) Gas Production Measurement and Transmission
5) PetE 3033, Petrophysics Laboratory
6) PetE 3036, Introductory Well Logging
7) PetE 4045, Drilling Engineering
8) PetE 4046, Well Design - Production
9) PetE 4051, Reservoir Engineering
10) PetE 4052, Reservoir Engineering
11) PetE 4085, Production Engineering
12) PetE 4088, Well Logging

b) Graduate Courses Taught

1) Experimental Studies of Non-Newtonian Fluids
2) PetE 7201, Advanced Reservoir Engineering
3) PetE 7280, Mathematical Simulation of Petroleum Reservoir Performance

c) Extension Courses Taught

1) A 15-week evening course in Reservoir Engineering at LSU Shreveport at request of Lou-Ark Section, Society of Petroleum Engineers of AIME - 1967.

2) A 15-week evening course in Reservoir Engineering at LSU Medical School, New Orleans, at request of Delta Section, Society of Petroleum Engineers of AIME - 1971.

d) Short Courses Taught

Special Instructor in International Association of Drilling Contractors Blowout Training School since 1973.

Special Instructor in LSU Advanced Well Control School for Deepwater Floating Drilling Operations since Oct., 1981.

e) Committees

1) General Editorial Committee, SPE of AIME (1967-1968)
2) Education and Professionalism Committee, Fall Meeting SPE 1970
3) E & A Standing Committee of SPE (1974-1978)
4) Faculty Advisor to LSU Student Chapter SPE (1968-1977)
5) Member of Committee to prepare three years of examinations for professional licensing of Petroleum Engineers for NCEE-1972
6) Advisory Committee, Division of Continuing Education (past)
7) Freshman Counseling (past)
8) Faculty Policy Committee (past)
9) Academic Matters Committee (1974-1980)
10) Student Affairs Committee (past)
11) Computer-Oriented Academic Program (past)
12) Admission, Standards and Honors (past)
13) Senior Academic Advisor, Petroleum Engr. Dept.
14) Curriculum Committee, Petroleum Engr. Dept.
15) Graduate Program Committee, Petroleum Engr. Dept.
16) Annual High School Seminar (since 1969)
17) COE Ad-Hoc Faculty Promotion and Tenure Review Committee (AY 1979-80 through AY 1981-82)
18) Departmental Promotions and Tenure Committee, 1979 to present (Chairman since 1980)
19) Search Committee for LSU Foundation Chaired Professorship in Petroleum Engineering
20) COE Task Force on Microcomputers (since August 1983)

f) Grants and Contracts

Principal Investigator, Louisiana Water Resources Research Institute Projects:

1) "Flow Model Studies of Displacement Processes in Anistropic Aquifers," A-023-LA, FY 1971, $10,700.

2) Continuation A-023-LA, FY 1972, $11,700.

3) "Physical Studies of Anisotropic Media with Applications to Ground Water and Waste Disposal Problems," A-032-LA FY 1973, $10,700.

4) Continuation of A-032-LA, FY 1974.

5) Co-Investigator with A. T. Bourgoyne and J. P. Langlinais, unsolicited research grant from Minerals Management Service of U.S. Dept. of Interior" The Development of Improved Blowout Prevention Systems for Offshore Drilling Operations," $1,862,000 (5-yr. program).

Co-Investigator with A. T. Bourgoyne and B. R. Hise, unsolicited research grant from United States Geological Survey "Development of Improved Blowout Prevention Procedures to be used in Deep Water Drilling Operations," Task I, 1978-79, $90,785.

g) Theses Directed

1) Liedner, Ernest J.: "The Rheological Properties of Bentonitic Cements" (June 1960).

2) Richter, N. J.: "A Study of the Rheological Properties of Oil-Well Cementing Compositions" (January 1965).

3) Overpeck, Andrew C. III: "Well Imaging and Fault Detection in Anisotropic Petroleum Reservoirs" (May 1969).

4) Taylor, Neale F.: "Thixotropic Characterization of the Problem of Restarting Flow in a Pipeline Containing a Gelled Oil" (May 1970).

5) Hinners, Donald L.: "The Design, Construction, and Testing of Consolidated Aniostropic Sand Models" (May 1972).

6) Rinard, Ronald E.: "Analog Simulation of Anisotropic Permeability" (May 1974).

7) Chemin, Louis O. Jr.: "The Simulation of Whole Core Permeameter Flow Geometry" (August 1974).

8) Bender, Catherine Vosin: "Pressure Gradient Reversals in Shut-in Wells' (August 1980).

9) Doyle, R. Scott: "Pressure Drop--Flow Rate Characteristics of a Spherical Type Blowout Preventer During Closure" (August 1981).

PROFESSIONAL SOCIETIES AND ACTIVITIES

1. Registered Professional Engineer in Louisiana - No. 9085
2. Society of Professional Well Log Analysts - No. 704
3. Society of Petroleum Engineers of AIME - No. 07796
4. Tau Beta Pi (Engr.)
5. Sigma Tau (Engr.)
6. Pi Epsilon Tau (Petr. Engr.)
7. Sigma Pi Sigma (Physics)
8. Pi Mu Epsilon (Math)
9. Sigma Xi (Physics)
10. B.S. Degree with Distinction (University of Oklahoma, 1953)
11. National Science Foundation, Faculty Fellowship (June 64-Nov. 65)
12. Pan American Oil Company Fellowship (Sept. 65-Aug. 66)
13. Continental Oil Company Scholarship (Sept. 66-Dec. 66)
14. Halliburton Education Foundation Award for Teaching Excellence (1969)
15. LSU College of Engineering Outstanding Faculty Recognition (1963 and 1968)
16. Lafayette Society of LSU Petroleum Engineers Outstanding Faculty Member Award (1982)

CONSULTING ACTIVITIES

1. U.S. Geological Survey - Detection of Methane in Groundwater.
2. U.S. Geological Survey - Explosive Hazards from Dissolved Gas in Groundwater.
3. Pittsburgh Steel Company - Expert Witness: Casing Failure during Well Completion.
4. U.S. Oil & Refining Company - Field Repressurization with CO_2.
5. Mrs. G. S. Dickerson - Technical Expert: Civil action over plant accident with salt cavern storage of LPG.
6. Jefferson Parish Water Department - Development of a saline aquifer for storage of fresh water.

7. Mr. Munsel M. Mayeus - Mathematical simulation of LPG flow in pipelines to include phase changes (flashing flow).

PUBLICATIONS

1. "Estimation of Gas Temperature from Mach Flow Around Obstacles," M.S. Thesis, University of Oklahoma, Norman (1957).

2. Holden, W. R. and Leidner, E. J.: "Rheological Properties of Gel Cements," World Oil (May 1960).

3. Craft, B. C., Holden, W. R., and Graves, E. D.: Well Design - Drilling and Production, Prentice-Hall, Inc., Englewood Cliffs, N. J. (1962).

4. Laboratory and Field Experiments in Drilling and Production Engineering, Edwards Brothers, Ann Arbor, Michigan (1963).

5. Harder, A. H. and Holden, W. R.: "Measurement of Gas in Groundwater," Water Resources Research, AGU (First Quarter, 1965) 1, No. 1.

6. Holden, W. R. and Caudle, B. H.: "Microstratified Permeability in Sandstones," presented at 42nd Annual Fall Meeting of Society of Petroleum Engineers of AIME, Houston, Texas (October 1967) SPE Paper 1819.

7. "Retrograde Condensate Fluids - Occurrence and Behavior," paper presented at midyear meeting of Interstate Oil Compact Commission, Mobile, Alabama (June 1968).

8. "Permeability Microstratification in Natural Sandstones," Ph.D. Dissertation, The University of Texas at Austin (January 1969).

9. Overpeck, A. C. and Holden, W. R.: "Well Imaging and Fault Detection in Anisotropic Reservoirs," Trans. AIME (1970).

10. "Fluid Flow Research at Louisiana State University," Anais do Segundo Encontro Sobre Escoamento em Meios Porosos, Faculdade de Filosofia, Ciencias E letras de Rio Claro, Brazil (October 1974) Vol. 1.

11. Holden, W. R.: "Well Control Operations for Subsurface Blowout Preventer Stacks," LSU/IADC Blowout Prevention Manual Chapter 15, LSU Blowout Prevention School; Baton Rouge, Louisiana (November 1978).

12. Holden, W. R., and Bourgoyne, A. T., and Hise, B. R., and Sullins, R. S.: "Well Control Procedures for Deepwater Drilling," Part 1, Ocean Resources Engineering (April 1978).

13. Holden, W. R., and Bourgoyne, A. T., and Hise, B. R., and Sullins, R. S.: "Well Control Procedures for Deepwater Drilling," Part 2, Ocean Resources Engineering (October 1978).

14. Holden, W. R., and Bourgoyne, A. T., and Hise, B. R., and Sullins, R. S.: "Well Control Procedures for Deepwater Drilling," Part 3, Ocean Resources Engineering (December 1978).

15. Holden, W. R., and Bourgoyne, A. T.: "An Experimental Study of Well Control Procedures for Deep Water Drilling Operations," presented at 14th Annual Offshore Technology Conference, Houston, Texas (May 1982) OTC Paper 4353. (Publication Pending)

16. Elfaghi, F. A., Langlinais, J. P., Bourgoyne, A. T. and Holden, W. R.: "Frictional Pressure Losses for Single-Phase and Two-Phase Flow of Drilling Muds," Jour. Energy Resources Technology, Vol. 105 (September 1983).

17. Langlinais, J. P., Bourgoyne, A. T. and Holden, W. R.: "Frictional Pressure Losses for the Flow of Drilling Mud and Mud/Gas Mixtures," presented at 58th Annual Technical Conference of Society of Petroleum Engineers of AIME, San Francisco, CA (October 1983) SPE Paper 11993.

18. Langlinais, J. P., Bourgoyne, A. T. and Holden, W. R.: "Frictional Pressure Losses for Annular Flow of Drilling Muds and Mud-Gas Mixtures," submitted to Jour. Energy Resources Technology (In Review).

PROFESSIONAL RESUME

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Louisiana State University
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PERSONAL INFORMATION

Date of Birth	September 25, 1924
Nationality	French
Marital Status	Married, three children (28, 25 and 23)
Home Address	2100 College Dr. #194 Baton Rouge, La. 70808
Home Phone	504 - 928-4622
Foreign Languages	English (fluent spoken and written) Spanish (spoken and written) German (7 years of classes) Russian (1 year of classes) Chinese (1 year of classes)

EDUCATION

Ecole Nationale Superieure d'Arts et Metiers, Cluny, 1944 Silver Medal

Ph.D. in Spectronomy, Faculty of Science, University of Lyon, France, 1965.

MILITARY SERVICE

1967	Received commission
1956	Promoted to Lieutenant of the reserves
1946	Officer of reserves at Equipment Applications School in Bourges, France
1945	Fought on the Atlantic front (La Rochelle)
1944	Enlisted in French Home Forces

PROFESSIONAL EXPERIENCE

1984-	Professor Louisiana State University

Teaching assignment:

PETE 3036 (1)

PETE 3036 (2) Introductory to Well Logging

Research assignment:

Head of Well Logging Research and teaching facilities

1982-1984 Visiting Professor at the University of Houston, Department of Electrical Engineering

Teaching assignment:

ELEE 5340: Introduction to well Logging

ELEE 7397: Well Log Interpretation

ELEE 6111: Advanced Well Logging Seminar

Research assignment:

Participation in the Well Logging Laboratory work

1966-1981 Lecturer of well logging at Ecole Nationale Superieure du Petrole et des Moteurs, France

Teaching of borehole measuring methods and their interpretation.

In charge of training:

10 to 15 economists
20 to 30 geologists-geophysicists
20 to 30 drilling-production engineers
3 to 4 foreign trainees per year

Leading contributions:

Two text books published in 1968 and 1981
Exercise book in 1970
Simplified book in 1970

1960-1966 Head of Direct Prospection Project at the French Petroleum Institute, France

Fundamental research on direct prospection

Responsibility for two research scientists and two technicians

Contact with two university laboratories

In 1960, appointed Senior Research Scientist

1958-1960	Head of Mud-Logging Laboratory at the French Petroleum Institute, France
	Measurements of parameters during drilling
	Directly responsible for:
	3 well-logging teams 2 scientists and 2 technicians development of new equipment
1952-1958	Research Scientist with Schlumberger South America Corporation in Houston, Texas
	Designing and building new well-logging equipment
	Chief of Formation Tester project Project led to commercial success
1947-1952	Field Engineer with Schlumberger Well Surveying Corporation
	Successively:
	Field Engineer in Trinidad, Columbia Chief of Center in Colombia Chief of Division in Venezuela
1946-1947	Engineer with Etablissements SADER
	Miscellaneous construction jobs

PUBLICATIONS

Articles	37 articles in different magazines in the field of borehole geophysics, physics of solids and fundamental physics
Books	Five books on borehole geophysics
Patents	Several patents taken out in France and/or abroad

REFERENCES

Attached.

LIST OF TEXTBOOKS
Authored or Co-Authored by
Dr. Robert DESBRANDES

1. Petroleum Dictionary: Well Logging, Drilling and Production Techniques; Russion, French, English and German. Desbrandes R., Dupuy M., Ketchian S., and Pfanukuch, Editions Technip, 1955, Paris

2. French Dictionary of Technical Terms Used in the Petroleum Industry, Moureau and Rouge, Editions Technip, 1963, Paris (Dr. Debrandes contributed Well Logging terms).

3. Theory and Interpretation of Well Logs, Desbrandes R., I Vol., 578 pages, 483 Figures. Editions Technip, 1968, Paris

4. Principles of Well Logging, Desbrandes R. and Dadone R., I Vol., 55 pages, Edition Technip, 1968, Paris

5. Collection of Well Log Examples, Desbrandes R., I Vol., 20 examples and solutions, Edition technip, 1970, Paris

6. Teorija i interpretacija resul'tatov geofizicheskikh metodov issledovanija skvazhin, Desbrandes R., I Vol., 288 pages, Editions "Nedra", Moscow, 1972, Russian translation and adaptation of "Theory and Interpretation of Well Logs".

7. Ce jin li luh he jie shi, Desbrandes R., In print, Petroleum Exploration and Exploitation Research Institute Peking, China Chinese translation and adaptation of "Theory and Interpretation of Well Logs".

8. Well Logging in Boreholes, Desbrandes R., I Vol., 550 pages, 450 figures, Editions Technip, 1982, Paris

9. Encyclopedia of Well Logging, Desbrandes R., I Vol., 600 pages, 500 figures, Editions Technip/Gulf Publishing, 1985, Paris/Houston.

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Authored or Co-Authored by
Dr. Robert DESBRANDES

1. "Contribution to the Study of the Speed of Seismic Waves", Co-authors: X. Reverdy and A. Lagarde IFP Journal (Revue), Vol. XIV, No. 4-5, April-May, 1959.

2. "On the Reaction of Ionized Rare Gases to Brief Impulse", Co-authors: G. Norel and Y. Morineau, C.R.A.S., Vol. 252, p. 2393-2395, April 17, 1968.

3. "Coupling between Network Vibration and Dielectric Absorptions", Proceedings of the XII AMPERE Sym., Bordeaux, September, 1963, North Holland Publishing Co., Amsterdam.

4. "Correlation Between the Bands of Dielectric Absorption and the Attenuation of Brief Impulses Along Coaxial Lines"., C.R.A.S., Vol. 257, p. 2829-2832, Nov., 1963.

5. "Measurement of the Speed of Acoustic Waves in Coal", Co-author: T. Schwaetzer, IFP Journal, Vo. XX No. 1, January, 1965.

6. "New Technique Showing Electrons-Phonons Interaction Type: Application to Hydrocarbons". Ph.D. Thesis, Faculty of Science, University of Lyon, France, February, 1965.

7. "Characterization of Hydrocarbons by Phonon Spectrum", IFP Journal, Vol. XX No. 5 May, 1965.

8. "Vibrational Interactions of Dielectric-Metal Contact", Revue Generale d'Electricite' Vol. 74, No. 12, December, 1965.

9. "Quantum Emitter of Gravitational Radiation". Paper presented at the 1966 Contest of the Gravity Foundation, New Boston, Conn., paper classified "Outstanding" by the Jury.

10. "Future Prespectives of Well Logging", IFP Journal, Vol. XXII No. 6, June, 1967 p. 935.

11. "Experimental and Theoretical Study of the Propagation of Electromagnetic Pulse of Short Duration Through the Earth, co-authors: R. Gabillard, J. Marchant, Conference on M.F., L.F., and V.L.F., Radio Propagation, I.E.E. London, November, 1967.

12. "Experimental and Theoretical Study of Electromagnetic Propagation in a Geological Waveguide, co-authors: R. Gabillard, F. Louage, J. Fontaine, Conference on M.F., L.F., and V.L.F., Radio propagation, I.E.E. London, November, 1967.

13. "Study of Gravitons-Phonons Interactions", co-author: J. L. Grossiord, paper presented to the French Association for the Advancement of Sciences, Nancy, France, July, 1968.

14. "A Model of the Gravitational Radiation of Solids," co-author: L. E. Halpern, Ann. Inst. Henri Poincare. Section A. Vol. XI, n° 3, 1969, p. 309-329.

15. "Telelog, an Electromagnetic Method of Directional Exploration at Great Distance from Borehole," co-authors: R. Gabillard, R. Louage, Z. Bassiouni, SPWLA - 12th Annual Logging Symposium, Dallas, May 2-5, 1971.

16. "Telelog Spots Oil Strata 3,000 ft. from Wellbore," co-authors: R. Gabillard, F. Louage, Z. Bassiouni, World Oil, September, 1971, p. 60.

17. "Thirty-seven Ways to Improve your Well Completions," World Oil, April, 1972, p. 71.

18. "A New application of Telelog: Locating Oil or Gas Field Limits," Co-authors: A. Bassiouni, R. Gabillard, E. de Gelis, SPWLA-13th Annual Logging Symposium, Tulsa, May 1972.

19. "Comparative Interpretation of Instantaneous and Delayed Well Logs":, SAID 1st Annual Symposium, Paris, April, 1972.

20. "Specific Surface of Rocks and NMR Logs", co-authors: Y. Crosnier, R. Gabillard, and J. Citerne, SAID 1st Annual Symposium, Paris, april, 1972.

21. "Telelog, New Exploration Method at Great Distance from Borehole":, Petrole Information, March, 1972, p. 16.

22. "Principles, Operation and Application of the Telelog", Petroleum Industry in Europe, No. 430, May, 1972, p. 9-19.

23. "What Is New in Downhole Operating Technology," World Oil, June, 1973, p. 74.

24. "New Well Logging Technique by Ultrasonic Reflection", co-author: G. Norel, IFP Journal, July-August, 1973, p. 587.

25. "Possibilities Offered by Modern Electronics in the Field of Electric Well Logging," 24th International Geophysical Symposium. Cracovie 4-7, September, 1979.

26. "Sub-Sea Telecommande and Remote Measurements" Part I and II", FORAGE (Drilling), No. 83, April-June, 1979 and No. 84, July-September, 1979.

27. "Electric Cable Formation Tester", FORAGE, No. 85, October-December, 1979.

28. "Control of Directional Boreholes by the AZINTAC Tool", FORAGE, No. 87, January-March, 1980.

29. "Production Well Logging Part I and II", FORAGE, No. 88, April-June, 1980 and No. 89, July-September, 1980.

30. "Tubing Perforations", FORAGE, No. 90, January-March, 1981.

31. "Logging of Relief Wells", FORAGE, No. 91, April-June, 1981.

32. "Well Logging Technique for the Evaluation of Mineral Resources" FORAGE, No. 92, July-September, 1981.

33. "Well-Site Recording and Interpretation of Well Logs", FORAGE, No. 84, July-September, 1979.

34. "Geothermal Well Logging", FORAGE, No. 93, Oct.-Dec., 1981.

35. "Borehole Orientation Measurement by Inertial Measurements, Part I and II", FORAGE, No. 96, July-Sept., 1982 and No. 97 Oct.-Dec., 1982.

36. "New Developments in Directional Drilling", Petrole Informations, No. 1561, January, 1982.

37. "Advances in remote-controlled drilling", Co-author P. Morin, Journal of Canadian Petroleum Technology", Nov.-Dec., 1982, Montreal.

LIST OF PATENTS
Dr. Robert DESBRANDES

1. "Helicoidal ply packer" U.S. n° 2 872 230, 1959.

2. "Short Duration Pulse Energy Measuring Device Using a Gas Tube Whose Degree of Ionization is Varied by the Pulse Itself" U.S. n° 3.173.090 (March 1965), France n° 1.313.726, W. Germany 1 261.598, Austria 22 750, Canada 714 719, Brazil 71 710, (Nov. 1962).

3. "Method of Corps Identification", French Patent 1.458.060, July 31, 1963.

4. "Method and Equipment for Hydrocarbon Detection" co-author: C. Bene, French Patent 1.459.739, October, 1963.

5. "Method and Equipment for the Detection of Subsurface Discontinuities of Electric Resistivity: co-author: R. Gabillard, French Patent #1.529.584, October 27, 1966 and May 13, 1968.

6. "Transmitter-Receiver of HF Gravitational Waves" French Patent 1.557.617, May 26, 1966 and Certificate of addition 94.503, October 25, 1966.

7. "Magneto-Electric Tool for the Detection of Subsurface Discontinuities of Electric Resistivities" France 1.603.023, June, 1968, France n° 1.578.713, U.S. n° 3.609.521, Canada n° 843.552, Iran n° 7 639, Venezuela n° 22 359, July 14, 1969.

8. "Prospection Method for Formations Surrounding a Wellbore", co-authors: R. Gabillard and F. Louage, French Patent 1.602 303, June 24, 1968, addition certificate 96 956, addition certificate 96 508.

9. "Methods and Equipment to Conduct Sensitive and Exact Measurements of Rock Properties Around a Borehole", co-authors: M. M. Lebreton, Morlier, Sarda, France n° 1592 555, July 22, 1968, Canada n° 942 211 July 69, U.S.A. 3 613 072 july 69, France 2 055 511, May 11, 1969.

10. "Method and Equipment for the Detection of Discontinuities in Formations Around Boreholes", co-authors: Lebreton, Morlier and Sarda, French patent 2 057 511, May, 1969.

11. "Method and Equipment of Subsurface Prospection", co-authors: Gabillard and Louage, French patent 2 151 428, April 1971, Canada 829 580, Dec. 1971.

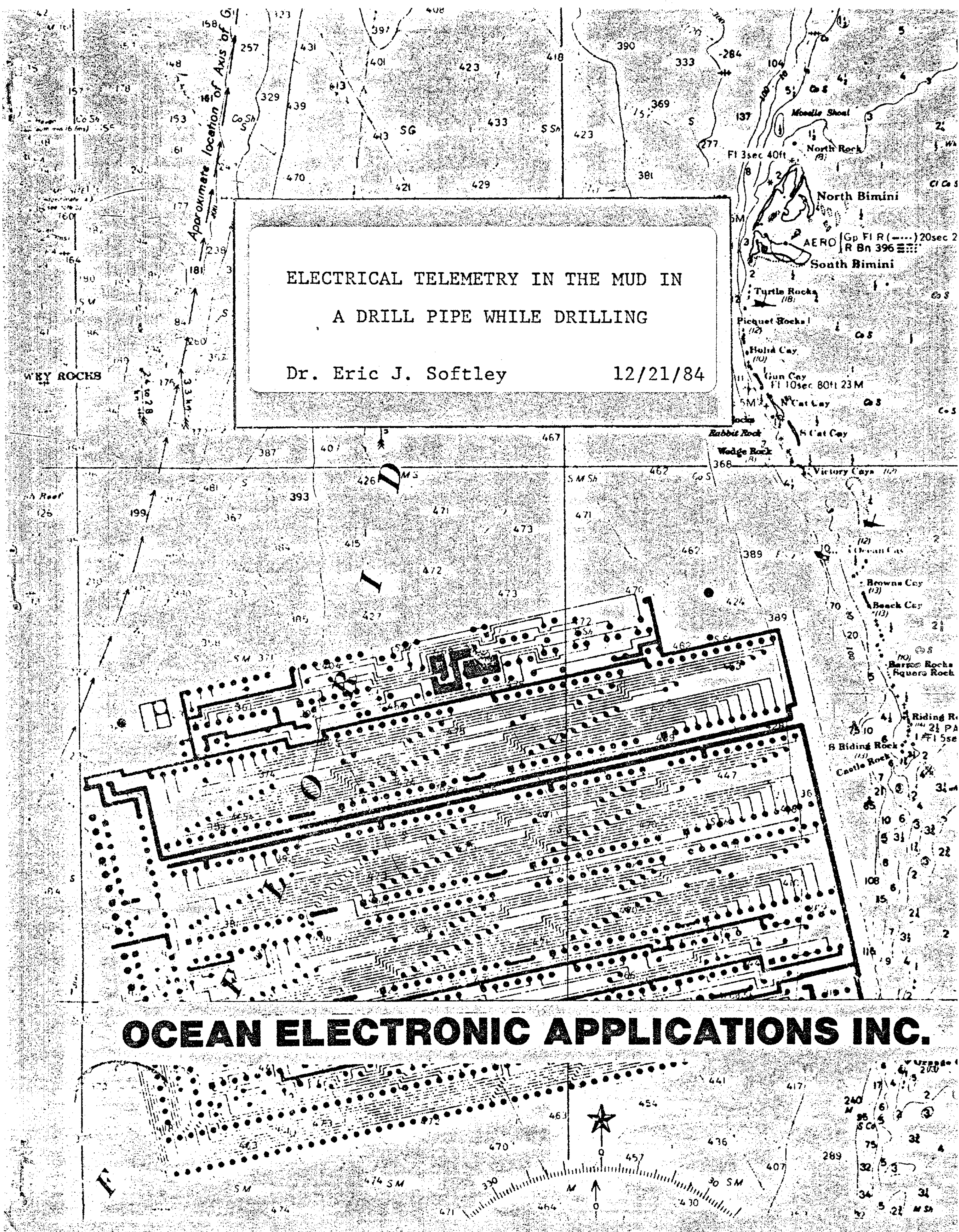
12. "Method and Equipment for the Determination of the Characteristics of Geologic Formation by Acoustic Signals", France 2 145 100, July 1971, U.S.A. 3 781 784, May, 1972.

13. "Method and Equipment of Exact Determination of the Acoustic Impedence of Geologic Formations Around a Wellbore", co-author: M. Norel, France: 2 172 808 February, 1972, U.S.A. 3 883 841, February, 1973, Canada 974 081, February, 1973, France 2 270 602, May, 1974.

ELECTRICAL TELEMETRY IN THE MUD IN A DRILL PIPE WHILE DRILLING

Dr. Eric J. Softley

12/21/84



OCEAN ELECTRONIC APPLICATIONS INC.

ELECTRICAL TELEMETRY IN THE MUD IN A DRILL PIPE WHILE DRILLING

Subcontract Proposal To

Louisiana State University
Petroleum Research Institute
Baton Rouge, LA

By
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21 December 84

1. Introduction

The need for data telemetry during drilling has been recognized for some time. The availability of data at the surface allows for rapid monitoring of the drilling process and more importantly provides valuable information before a kick takes place and during subsequent shutin and circulation of the kick.

Most of the work on MWD to date has concentrated on pressure pulse or continuous wave pressure telemetry systems. These have provided valuable support for the drilling process. The pressure telemetry systems, however, have some significant drawbacks. First attenuation of the signal increases rapidly with increasing acoustic frequency. As a result the inherent data rate is essentially limited to a few baud and this in turn provides quite slow effective information rates. Secondly the signal attenuation increases with increasing mud weight. Therefore if the mud weight is increased, a typical action which can follow taking a kick, the telemetry is likely to be lost at a very critical time.

To understand the data rate requirement it is important to consider the overall system requirements. For a MWD system to be practical in both engineering and financial terms the system should provide sufficient information for drilling efficiency and safety considerations. To that end it should provide information usually provided by well logging as well as bore hole pressures, drill angle and direction. Hence a typical system might provide the following:

Bore hole pressure (2 values)
Bore hole Deviation
Bore hole azimuth
Tool face gravity angle
Tool face magnetic angle
Downhole weight on bit
Annulus temperatures
Formation resistivity
Formation radioactivity
Downhole sonic velocity

If this information is available on a continuous and reasonably rapid basis then three information needs can be at least partially satified. Drilling efficiency can be monitored and controlled. Secondly the last four data items aove can be combined to give an early indication of gas influx into the return mud. Thirdly if the well is shut in and the kick circulated out the direct measurement of bore hole pressure provides valuable control information during this process.

In summary a set of typical data requirements can be estimated. The data can be organized into frames of words and a single frame would be logically about 16 words in length with each word 16 bits in length. Overhead might add about 50% to grow in size and complexity so that data frames of length 600 bits are not unreasonable.

If the data is sent in complete form a data rate of 1/2 baud would require 20 minutes to transmit a complete set. Since acoustic telemetry, either pulse or continuous wave, has data rates of this order it is necessary to limit the data transmitted to a few parameters at any one time. This does not satisfy the overall requirement of providing information for all three functions.

If a data rate of 300 baud were possible then it would take 2 seconds for each complete frame of data. Three such frames would take 6 seconds and allow demonstration and self checking for data consistency. Using the four indicated parameters for kick detection it would then be possible to identify a kick in about 10 seconds. This response is adequate to warn the drill operators and to allow human intervention.

Thus for a system which can satisfy multiple functions for drilling efficiency and safety the acoustic telemetry does not provide a sufficiently fast response. As a result the acoustic telemetry now in use must still be supported by conventional wire logging. Also early kick detection is really not feasible.

A more promising approach to obtaining higher data rates has recently been examined by the author in conjunction with work at the Petroleum Research Institute at Louisiana State University. The concept involves using electrical propagation in the mud if the mud is insulated from the drill pipe.

The system in simplified form is shown in figure 1. Some form of insulation is placed on the inside surface of the drill pipe. This insulation is assumed to extend from a short distance above the drill bit to the top of the Kelly. At a distance above the insulation lower limit a transmitter is installed with electrodes contacting the mud. Similar receive electrodes are located at the lower end of the Kelly. The electrical signal passes through the mud from the transmitter to the receiver.

In the system the drill bit and the swivel assembly above the Kelly are both considered as uninsulated. Also the drill pipe insulation is also considered imperfect.

It is possible to make some statements about the system.

1. The signal will attenuate due to the electrical resistance of the mud in conjunction with capacitive loading from the finite insulation thickness and resistive loading from insulation leaks.

2. The transmitter will be loaded by the electrical path to the drill bit or to where the drill pipe or collars are no longer insulated.

3. The receiver electrode impedance will depend in part on the electrical path to the swivel assembly.

The design of such a system will involve engineering effort for the transmitter design and packaging, design for the receiver and the electrodes, and design and development of a suitable insulation technique. Before this activity was initiated it was felt that examination of the physical processes was important so that the signal attenuation, electrical noise, the effect of insulation thickness and leakage could be reliably estimated. A feasibility study has been performed for this purpose. This feasibility study allowed the development of a computer model to calculate signal strengths and a small scale telemetry experiment to evaluate the model and to determine the effects of insulation leakage, changing mud parameters, etc. on the telemetry.

2. Results of Work To Date -Propagation Study

A typical field applicaton might have the following parameters.

Pipe - 4 1/2 inch 3.8 inch inside dia.
Length 20,000 feet.

For the electrical propagation in such a pipe (when insulated) a simple electrical model can be devised. This is shown in figure 2. The resistive elements refer to the mud resistance per unit length and the capacitance is the shunt capacitance between the inner conductor, the mud, and the outer conductor, the pipe.

To calculate the attenuation these values must be known. The mud electrical conductivity can be measured using a test cell. A typical sample of mud is placed in a tube and using two outer electrodes a current is induced in the mud. The voltage across a sample is then measured using two inner electrodes. A variation of this approach is used in the mud probe shown in figure 3. The circuit shown uses a ten turn calibrated potentiometer to balance a bridge such that if the bridge is in balance the resistance of the potentiometer is equal to the resistance of the mud sample.

Using both this probe and a test cell samples of field muds were evaluated for their specific resistivity. Table 1 shows the results. For the field muds tested the specific resistivity varied from 0.5 to 2.2 ohms/meter/sq.meter in most cases with oil based muds having much higher values > 13.

The capacitance of the system can be calculated from the known geometry for different insulating materials. Material variations are not very large but the insulation thickness does strongly influence the values. Insulation thicknesses of 1/16 to 1/8 inch were calculated.

It became apparent during some early experiments that the simple model shown is not adequate. The problem lies in the electrical connection between the electrodes and the mud. If the mud is stationary (with respect to the electrode) the impedance of the electrode is relatively low but if the mud is flowing over the electrode a higher resistance value is observed and this value is frequency dependent.

To evaluate this problem a small test cell was fabricated. This cell uses a stationary electrode at the bottom of the cell and a rotating plate for the upper electrode. As such there will be a small center section which is not slipping and this section is insulated. The results with a single mud sample are reasonably consistent and are shown in figure 4. It is possible to devise a formula for the electrode impedance. In fact the electrode can be represented closely by a capacitance and resistance in parallel with both a funtion of surface area.

The electrical model then appears as in figure 5. In addition to the electrode impedance at the transmitting and receiving electrodes the influence of leaks at the insulation joints can now be handled. These leaks will occur due to the end fits of each drill pipe section and for our purposes the area of such a leak is the unknown parameter.

2.1 Small Scale Telemetry Experiment

It is apparent from the model that it is possible to perform an experiment on mud electrical telemetry on a smaller scale than the fullsize. Since the principal parameter is the resistance then a small diameter pipe will have higher linear resistance and can be simulated by a shorter length. To simulate the 4 1/2 inch pipe of 20,000 foot length a 1/2 inch diameter pipe of 400 foot length was used. In fact PVC pipe was used and the scale (based on internal diameter) was about 50 to 1. Using a heavy wall pipe working pressures of 800 lbs. were possible allowing realistic velocities (of order 20ft/sec) to be achieved and with Reynold's numbers well into the turbulent flow regime.

Since a thick wall PVC pipe in any configuration will have negligibly small shunt capacitance, electrodes were placed in the pipe every 10 feet to allow the electrical insertion of capacitors into the experiment. At the ends of the pipe sections of copper pipe were used to electrically simulate the drill bit and swivel sections. The transmitting and receiving electrodes were placed 0.6 feet from these ends to simulate a 30 foot pipe length as a typical offset. To simulate the drill pipe a length of 10 gage wire was strung along the experiment. All capacitive returns and simulated shorts were made to this wire.

This experiment was set up at LSU Blowout Prevention School during July 1984. Fluids for the experiment were pumped from a small mixing tank. This enabled relatively easy changes to the fluid. Initial experiments used water with salt added in stages to change the specific resistivity. Then light weight mud (8.9#) was used and salt also added to this in stages. The fluids used in the experiment are summarized in Table II. Note that specific resistances were the same order as the field muds. Note also that the addition of salt to the mud only made a slight change in the resistivity. The values are also shown in figure 7 and compared with sea water. The electrical conductivities of the experiment fluids is much lower than sea water.

The electrical telemetry was performed using the equipment shown in figure 8. A small transmitter based on a standard modem integrated circuit was fabricated. A square wave was used to simulate a typical NRZ data string. The resulting FSK signal was amplified and sent to the transmitting electrode. No attempt at impedance matching was made since power consumption was not important. Typical signals at the transmitting electrodes were 10 v p/p and 1 to 2 KHz with data modulation rates up to 325 baud.

The receiver used a two stage amplifier and combined low pass and high pass filters to provide low Q filtering of the signal. A phase locked loop squared the waveform and this was inputted to a matching demodulator.

Transmitting and receiving signals were measured and a check on the data telemetry made were pertinent. The results are shown in Table III. Typical attenuation values for the simulated drill string were 70 to 100 dB which allows a satisfactory level of received signal. In even the worst case a data rate equal to a maximum for the carrier frequency was achieved. Over 300 baud was always achieved.

To test the effect of leaks (shorts) in the insulation some of the electrodes were connected directly to the 'drill pipe'. As each section was shorted a small additional attenuation was observed.

It is interesting to compare the calculated values for the attenuation with those observed experimentally. Figure 9 shows this comparison. Using the improved model values of the calculated attenuation were within a few dB of the experimental values. Note that this calculation is valid for the small scale 1/2 inch pipe as well as the full size 4 1/2 inch pipe, 20,000 ft.

For a typical full size system with suitable power matching circuitry and with low level signal detection and decoding the calculated signals are shown in figure 10.

The effects of leaks can also be calculated. The leak calculation will depend only on the total surface area exposed to the drill pipe. For each leak equivalent in length to a single pipe diameter the attenuation is about 1 dB. While this does not appear great it shoud be noted that in a pipe length of 20.000 feet there are 667 joints and if each of these has a 1/16 inch gap there would be some 12 diameters of pipe exposed and an additional loss of 12 dB of signal. It is a measure of how good the end fits must be. The leak calculation is also shown in figure 10.

3. Proposed Study

The activity performed to date has indicated that the telemetry in the drill pipe would be expected to have reasonable signal levels. The noise levels, in as much as they are influenced by fluid flow and pump activity would also appear to be quite reasonable. At this point several unanswered questions remain. The key electronic questions are:

1. How to design the transmitter to maximize the signal

   a. Design of the electrodes and coupling signals.
   b. Design of a self adjusting output coupler.
   c. Packaging of the transmitter.

2. How to design a receiver for minimum error rate.

   a. Optimum data error rate for low signal to noise.

To evaluate two of these problems a study is proposed. The transmitter and receiver designs will be developed in the laboratory and tested using simulated noise and attenuation. In addition the laboratory setup will include local attenuation nodes to simulate leaks. The results will be examined parametrically.

Figure 11 shows the basic components. A small computer will be used to format data similar to a final system but with some engineering parameters set to preset values. Sensors for the measurement of pressure and temperature in the mud will be included and the data from these included in the data string.

The receiver design will include a front end that uses a probability detector to discriminate against noise. This design which was developed for satellite telemetry provides error free data transmission with signal to noise ratios as low as -4 dB.

The data from the receiver will be be sent to a specially programmed microcomputer. A single board z80 computer will be used and this will receive and store the data and calculate error rates. The computer can also be used to calculate engineering values from the data and to indicate such derived events as kick detection.

The installation used for the earlier experiments will be used for system evaluation. The computers, transmitter and receiver components will be installed at LSU and a series of experiments on data telemetry performed. Particular attention will be given to actual error rates under widely varying conditions.

4. Work Statement

The above activity can be summarised into a work statement:

1. Design and laboratory test of self adjusting output amplifier.

2. Design and construct data computer and transmitter assembly.

3. Design and fabricate receiver electronics and integrate with programmed microcomputer.

4. Test transmitter/receiver/computer system.

5. Assemble three components into system at LSU.

6. Perform mud flow tests for telemetry and error rates.

7. Analyse and report results.

5. Budget

Direct Labor (Principal Investigator)	$26,000
(Engineering Support)	$8,000
	$34,000
Expendable Materials	2,000
Travel and Living	2,400
Engineering Overhead 83.2% of direct labor	31,949
Total	$ 70,349

6. Principal Investigator

The Principal Investigator will be Dr. Eric J. Softley.

7. Period Of Activity

The period of this study will be 8 months starting as soon as possible after January 1 1984.

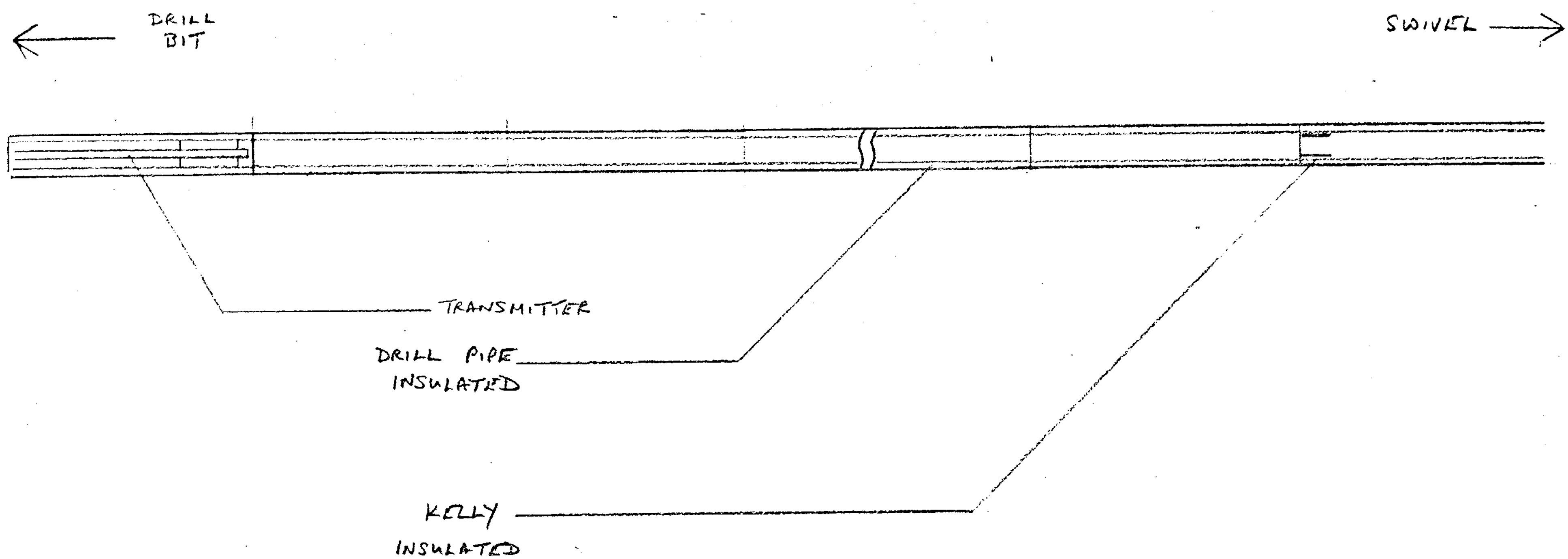
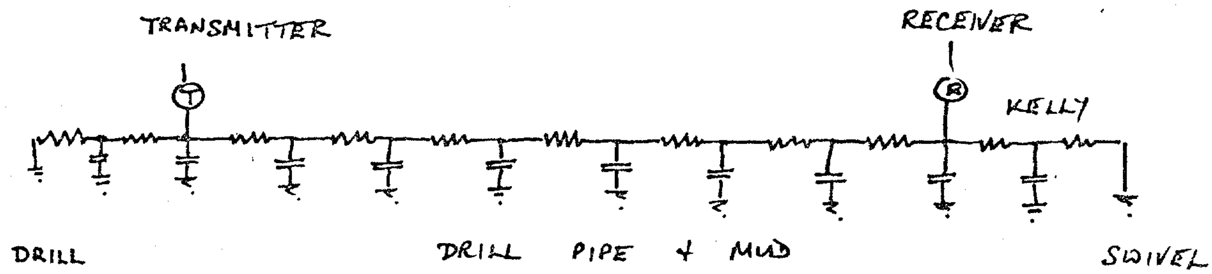


Figure 1. Simplified Drill String Arrangement

SIMPLE MODEL



RESISTANCE IS $\sigma L/A$

CAPACITANCE IS $2\pi eL/(\ln(D2/D1)$

ATTENUATION COEFFICIENT IS

$$Re\ ((R+iwL)(G+iwC))$$

NOTE.

1. For low frequencies (<100KHz) L and G insignificant
2. Attenuation is per unit length and therefore can scale problem by matching R and C per unit scale length.

Figure 2. Simple Electrical Model

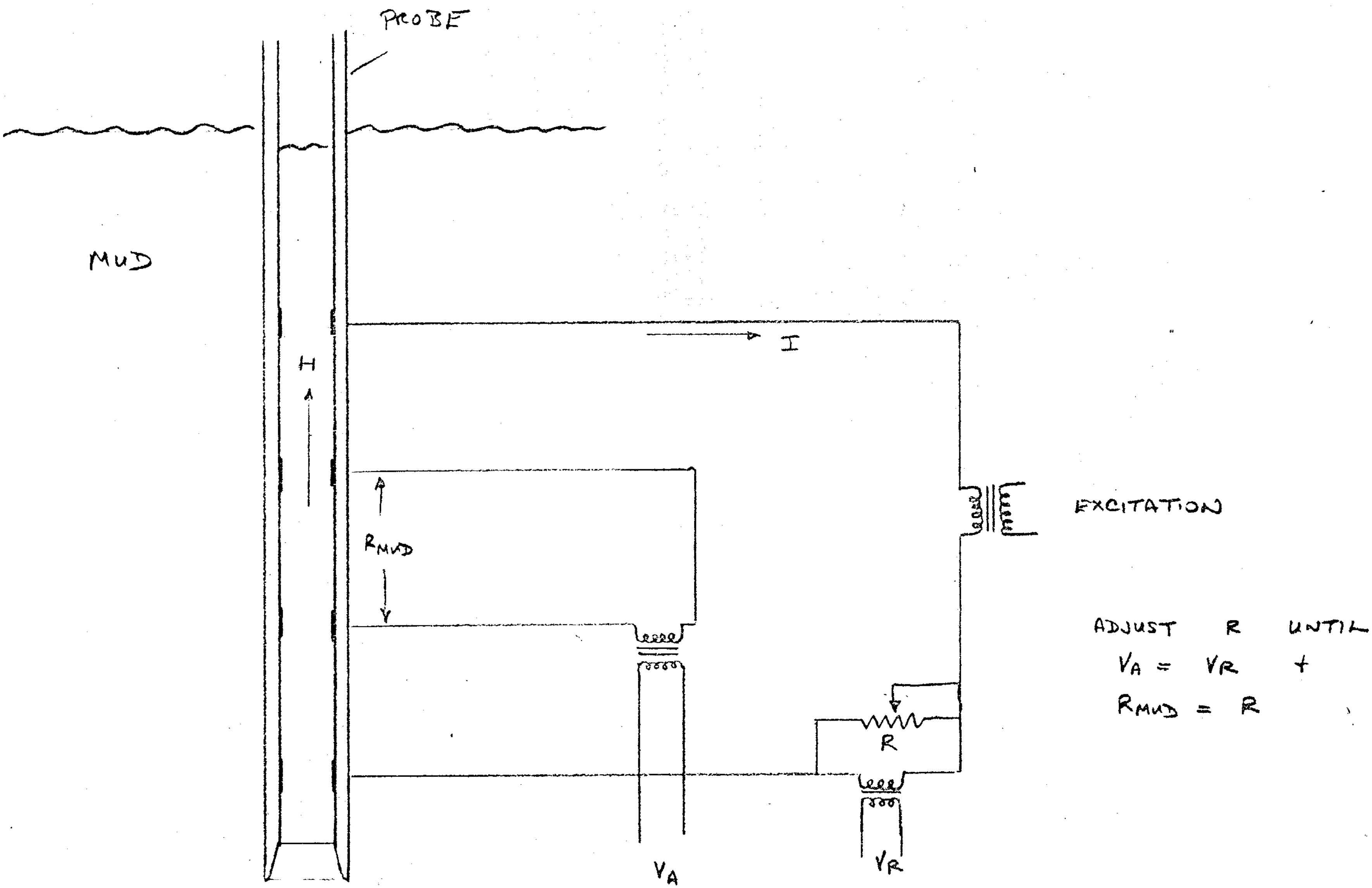


Figure 3. Use Of Insertable Probe For Mud Conductivity Measurement.

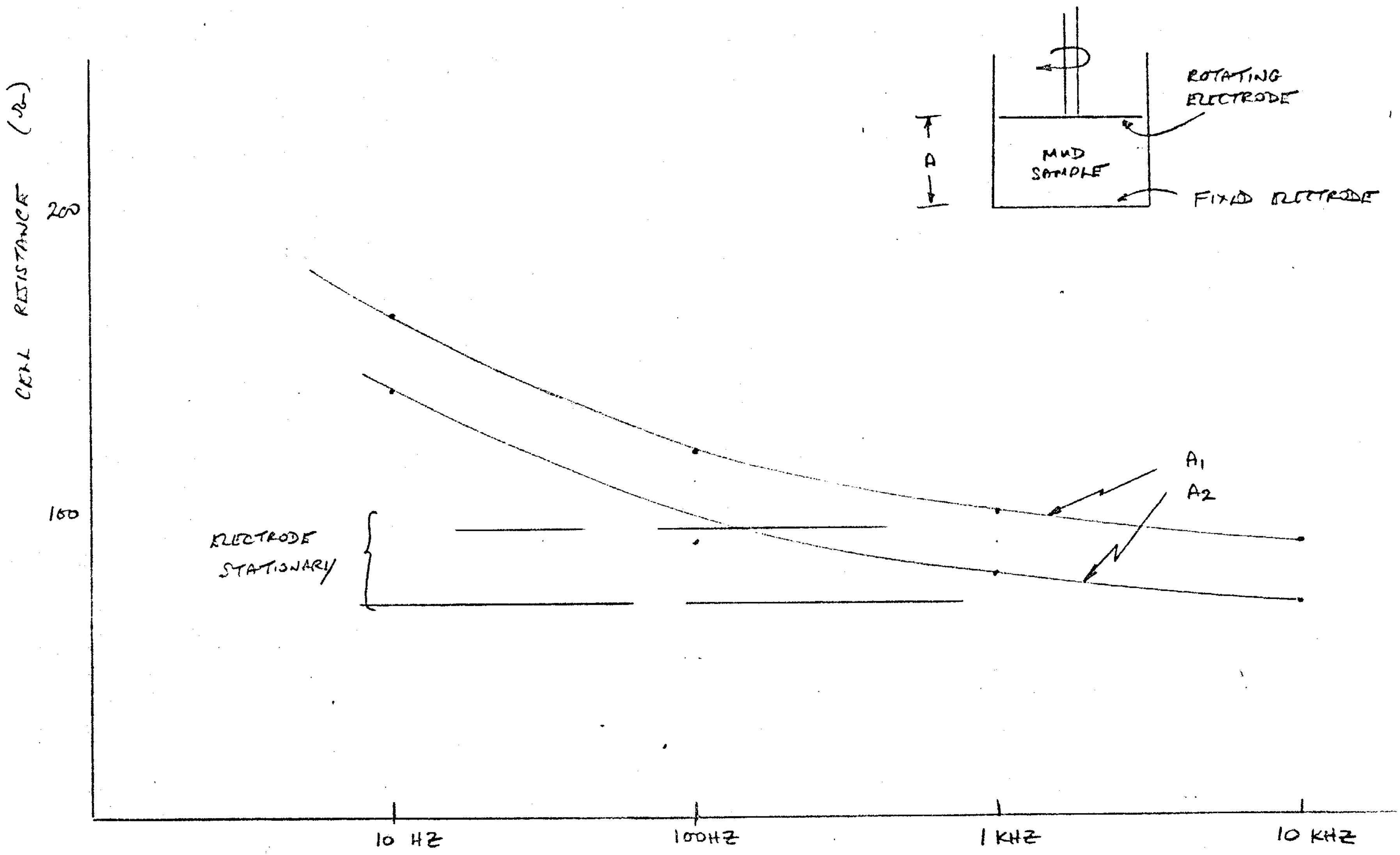
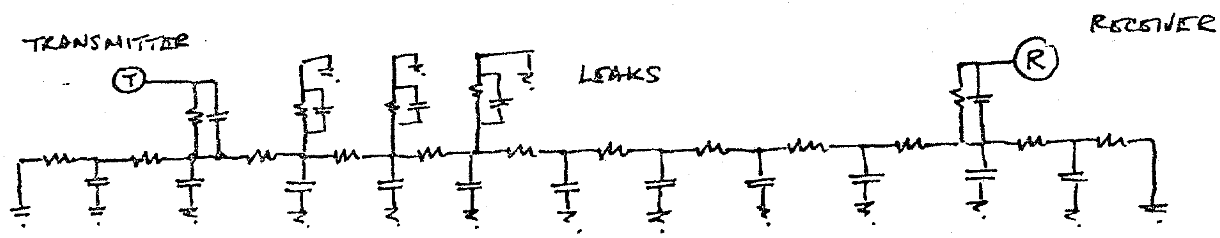


FIGURE 4. EFFECT OF SLIPPING ELECTRODE

IMPROVED MODEL

ELECTRODE IMPEDANCE IS COMPLEX AND DEPENDS ON THE STATE OF THE MUD. FOR MOVING MUD THE MODEL BECOMES



NOTE:

1 Insulation leaks at the pipe junctions become less important since they are shielded by the electrode impedance.

2 The capacitive component in the electrode impedance reduces the applied signal. This reduction can be partially overcome by adding a carrier to the signal.

Figure 5. Improved Electrical Model

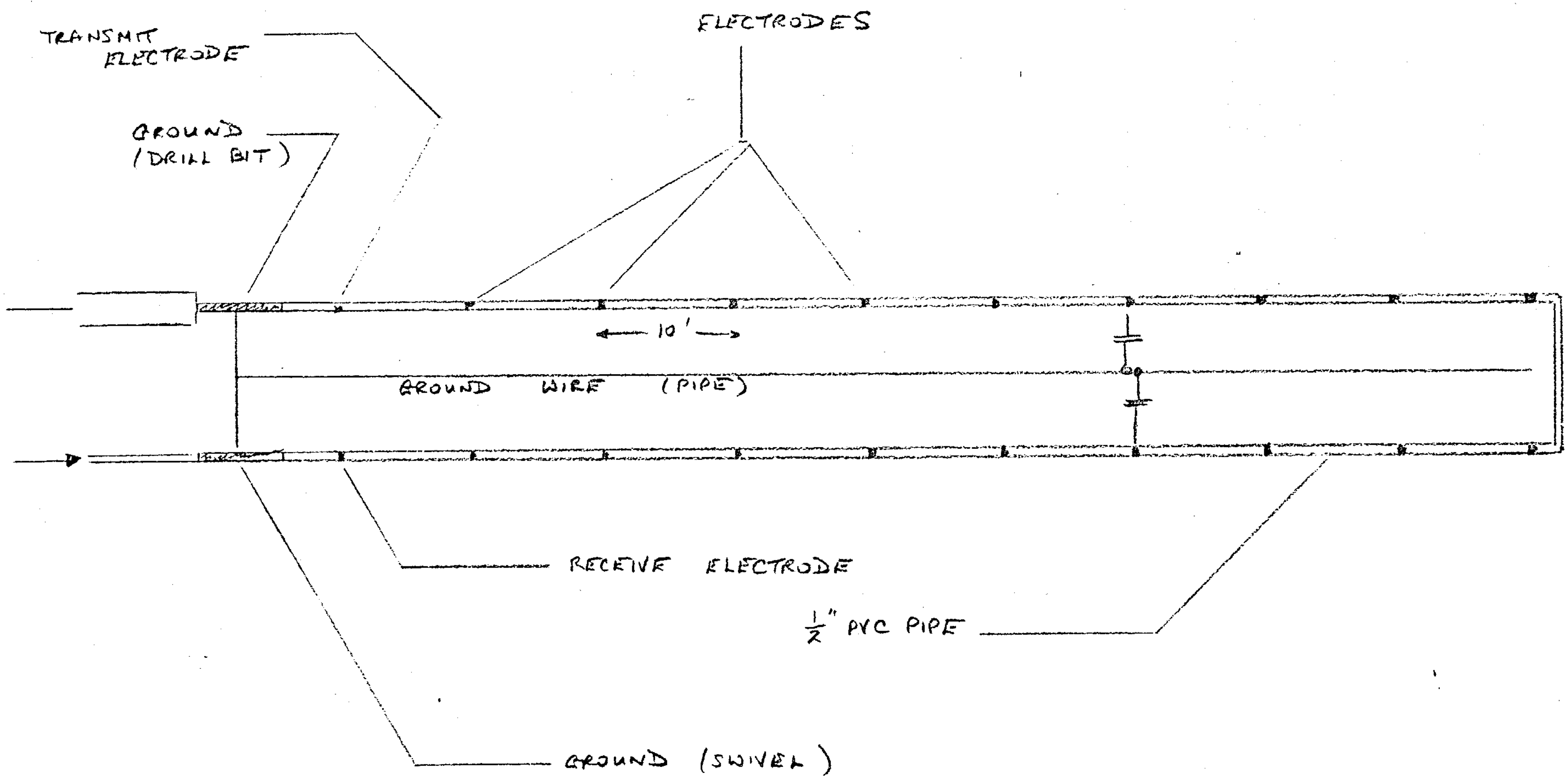


Figure 6. Arrangement For Small Scale Telemetry Experiment.

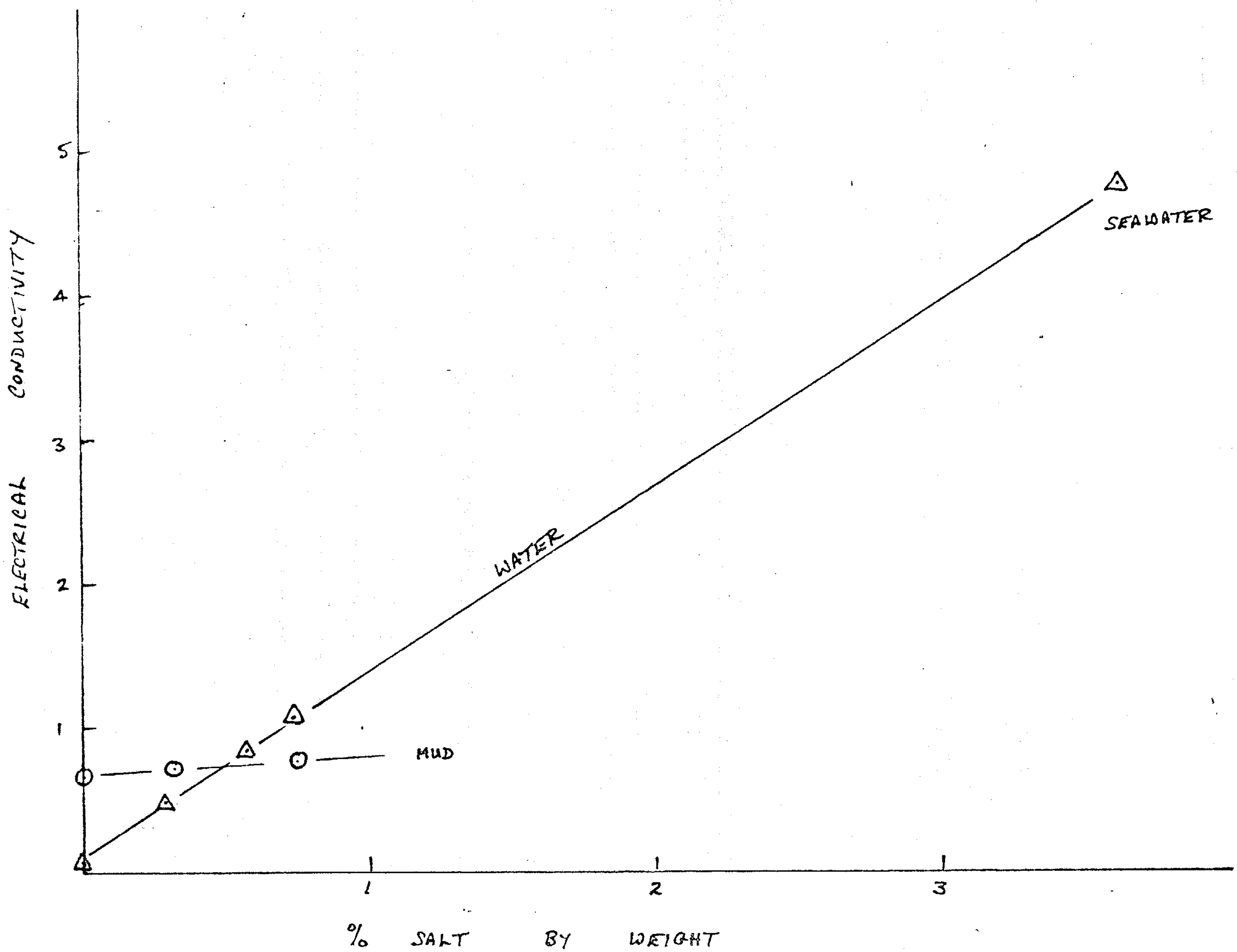


Figure 7. Variation Of Electrical Conductivity In Experiment Fluids.

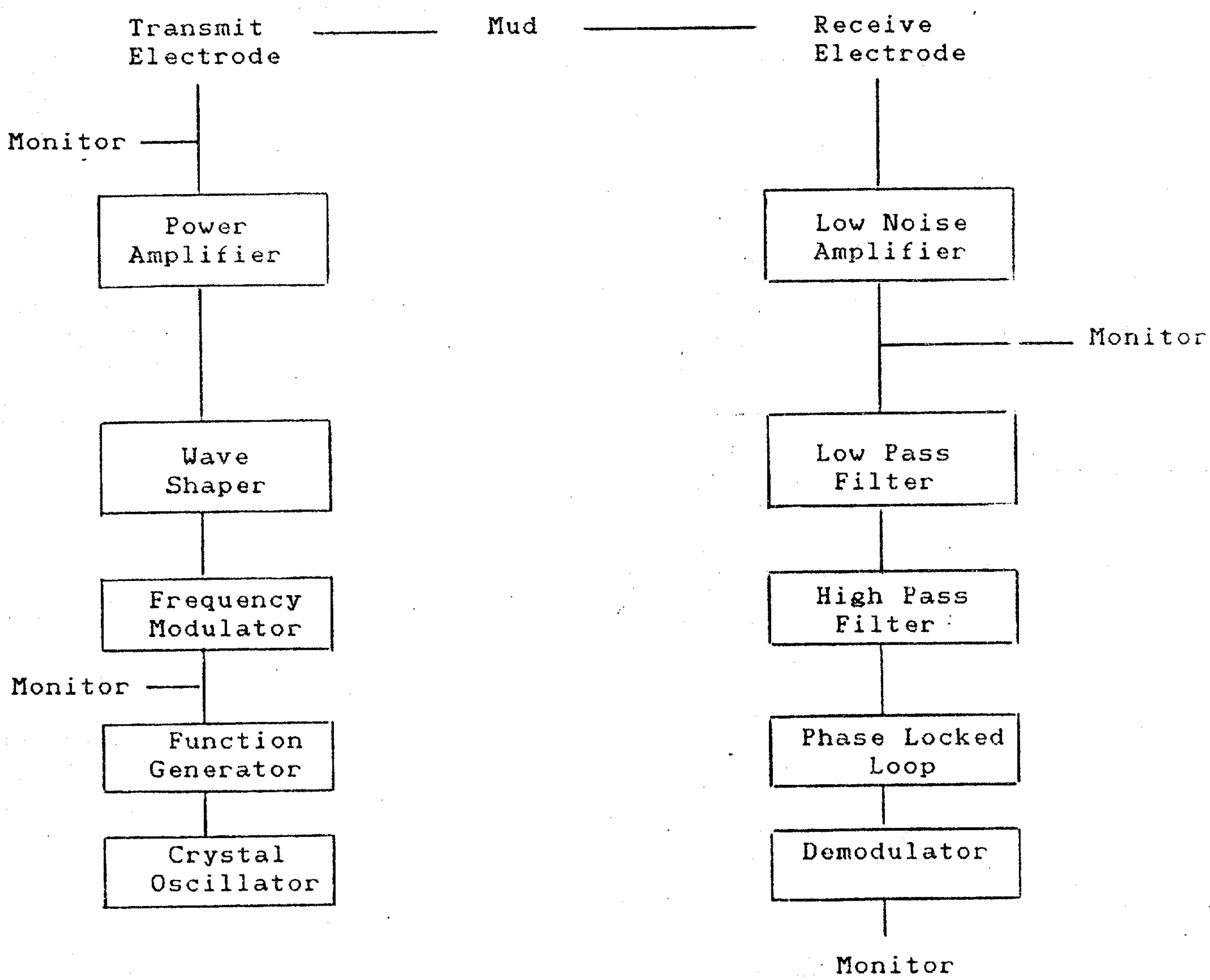


Figure 8. Electronics For Telemetry Experiment

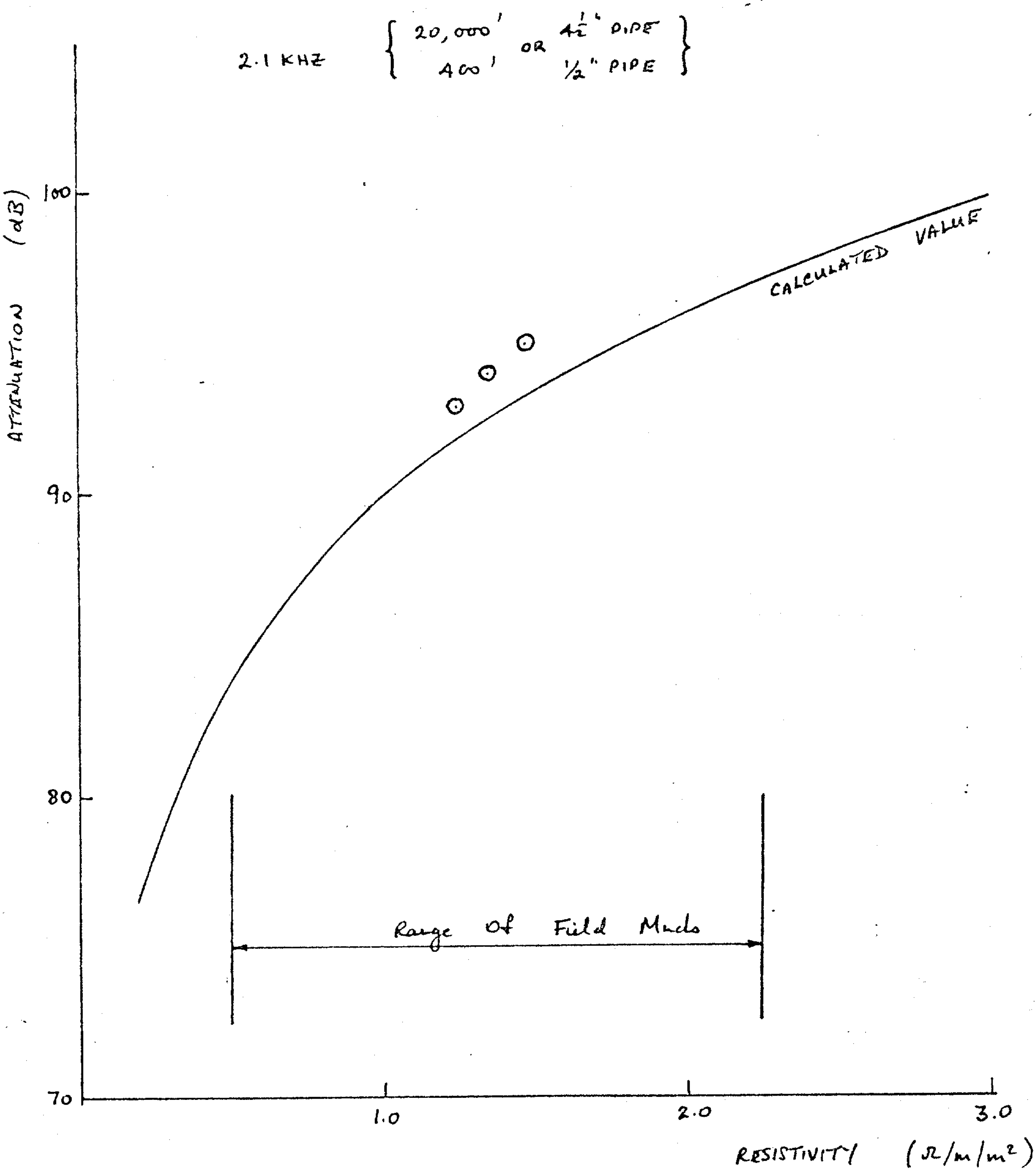


Figure 9. Comparison Of Calculated And Measure Attenuations For Experiment.

FULL SIZE SYSTEM CONSIDERATIONS

20,000 FT.
4 1/2 inch Pipe
2.1 KHz
300 Baud
30 ft. electrode offset
1 Watt Power

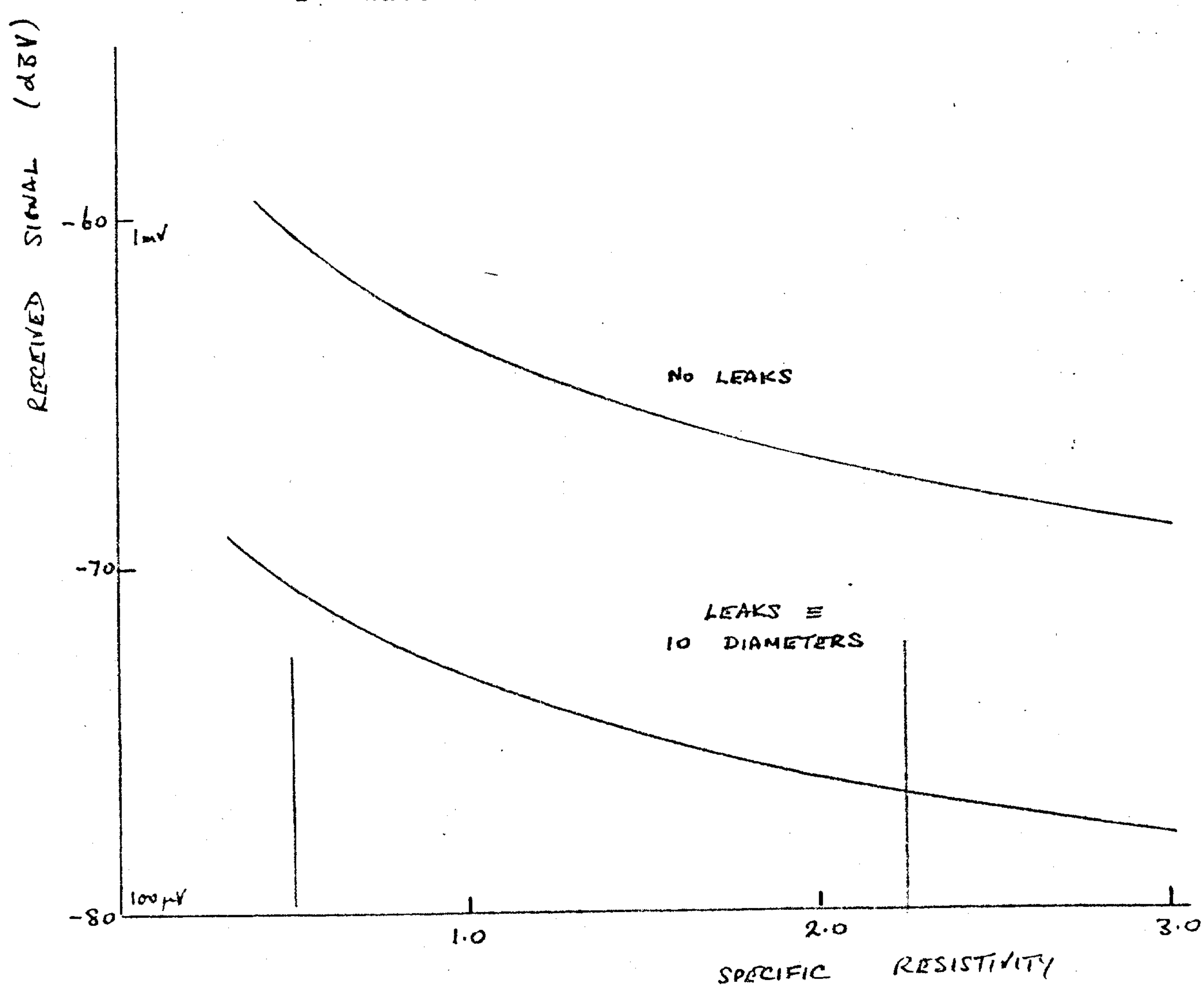


Figure 10. Typical Received Signals For Telemetry

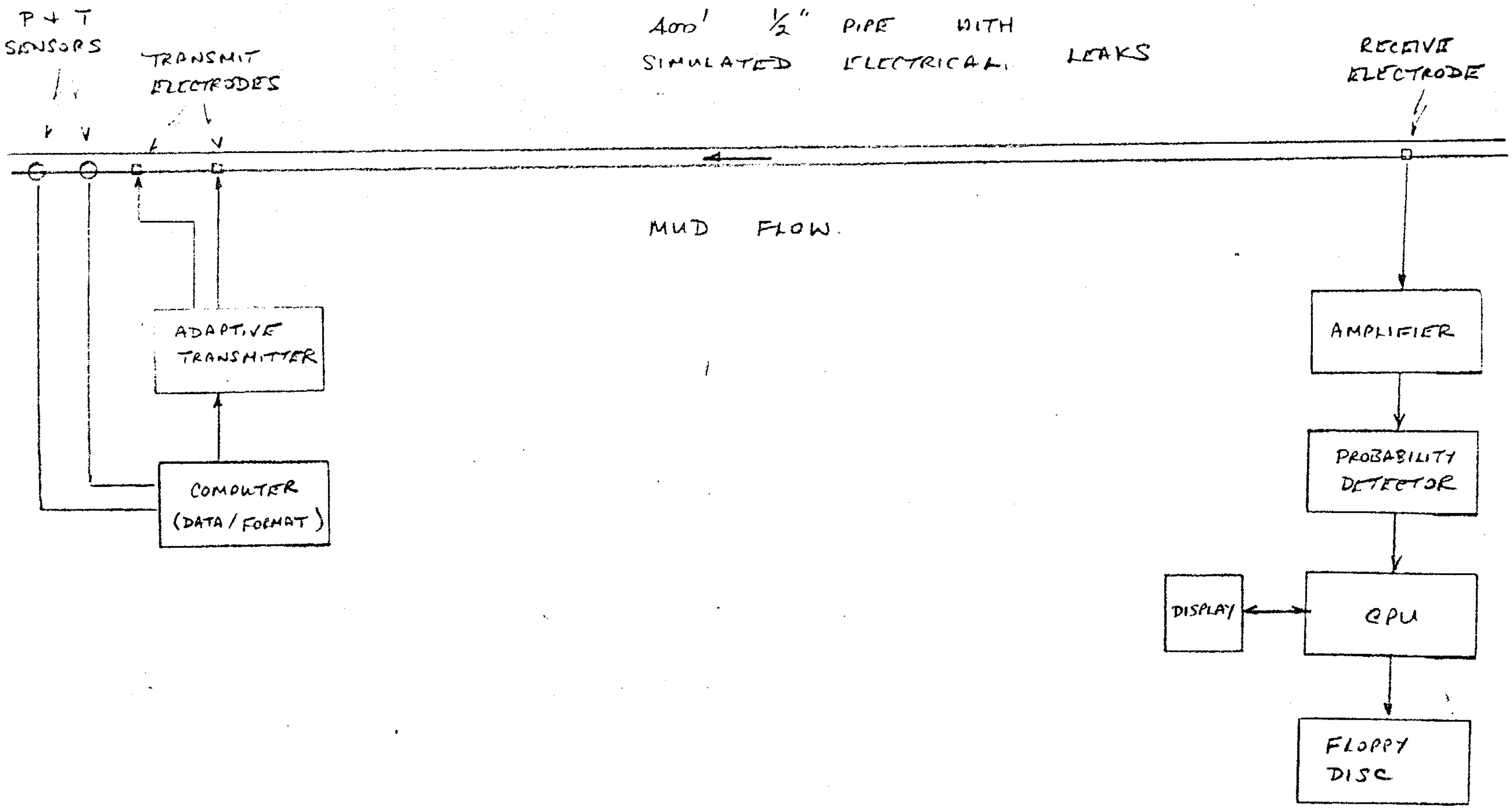


Figure 11. Electrical Telemetry Demonstration.

TABLE I

EXAMPLES OF MUD RESISTIVITY

Samples of field muds were analysed for resistivity to determine typical values. In some cases mud analyses are available.

SAMPLE NO	SAMPLE	TEST CELL	PROBE
1.	9.2 lb. KCL	2.3	2.23
2.	9.0 lb KOH	1.31	1.25
3.	10.0 lb LIGNO	0.98	1.00
4.	11.4 lb LIGNO/LIME	0.594	0.594
5.	12.5 lb OIL BASE	0.528	0.502
6.	14.5 lb OIL BASE	*	*
7.	11.0 lb LIGNO	0.506	0.568
8.	12.5 lb LOW LIME	*	*
9.	13.8 lb LIGNO	1.15	1.15
10.	14.9 lb DENSIMIX	8.63	*
11.	15.0 lb LIGNO	0.713	0.726
12.	17.3 lb LIGNO	0.713	0.752

Resistance shown is specific resistance in ohms/meter/sq.meter.
* means the value was greater than 13.

TABLE II

EXPERIMENT FLUIDS

NO.	BASE MATERIAL	SALT ADDED	% SALT BY ST.	SPECIFIC RESISTIVITY	SPECIFIC CONDUCTIVITY
1	WATER	0	?	11.7	0.08
2	WATER	8	.28	2.27	0.44
3	WATER	16	.56	1.21	0.83
4	WATER	20	.72	0.92	1.09
5	MUD	0	0	1.49	0.67
6	MUD	12	.31	1.41	0.71
7	MUD	28	.73	1.33	0.75
		by comparison			
Sea water			3.6	0.21	4.74

TABLE III

TABLE OF TEST RESULTS

No.	Sample No.	Matl.	Flow (psi)	Elec.	Res.	Freq (KHz)	Input (V)	Output (uV)	Noise (uV)	Atten (dB)	Data Rate
1	1	Water	300	2/3	11.7	1.0	2.9	370	75	78	
2	1					2.1	2.9	150		86	
3	2	Water			2.27	1.0	0.5	150		71	
4	2	+				2.1	0.8	90		79	
5	3	Salt			1.21	1.0	4.3	700		76	
6	3					2.1	4.1	300		83	
7	4				0.92	1.0	4.3	900		74	
8	4					2.1	4.3	740		75	
10	4			1/4		2.1	1.4	150		80	
11	4					1.0	1.5	150		79	325
Shorted #11 ,#28 and then both electrodes											
13	4	Water	250	1/4	0.92	2.1	3.6	370		80	
14						2.1	3.6	360		81	
15						2.1	3.6	150		88	325
Mud tests											
16	5	Mud		1/4	1.49	2.1	3.6	150	45	88	325
17				2/4		2.1	3.6	300		82	
18				2/3		2.1	3.6	1120		70	325
Installed capacitors in all electrode positions											
21	5	Mud		2/3	1.49	2.1	4.3	75	45	95	325
22						1.5	4.3	75		95	260
23						1.2	4.3	67		96	180
24						1.0	4.3	52		98	100
Increase salt content of mud in stages											
25	6	Mud		2/3	1.41	2.1	4.3	82		94	
27	7	+			1.33	2.1	4.3	90		93	325
Reverse transmitting direction											
29	7	Mud+		3/2	1.33	2.1	4.3	90		93	325
30											
Increase flow											
31	7	mud+	550	3/2	1.33	2.1	4.3	75	75	95	325
Electrode #11 shorted											
32	7		550	3/2	1.33	2.1	4.3	60	75	97	325
Shorten pipe 70											
33	7		550	3/2	1.33	2.1	4.3	300	75	82	325